

DESCRIPTION

POLYHYDROXYALKANOATE HAVING ESTER GROUP, CARBOXYL
GROUP, AND SULFONIC GROUP, AND METHOD OF PRODUCING
5 THE SAME

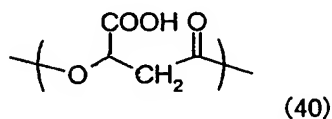
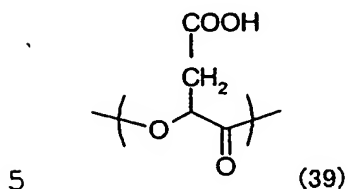
TECHNICAL FIELD

The present invention relates to a novel
polyhydroxyalkanoate and a method of producing the
10 same.

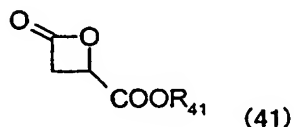
BACKGROUND ART

Biodegradable polymer materials have been
finding a wide variety of applications including
15 medical materials, drug delivery systems, and
environmentally compatible materials. In recent
years, in addition to those applications, the
biodegradable polymer materials have been requested
to provide new functions, and hence various studies
20 have been made. In particular, the introduction of a
chemically modifiable functional group into a
molecule of a polyhydroxyalkanoate typified by
polylactic acid has been examined. There has been
reported a compound into which a carboxyl group or a
25 vinyl group is introduced. For example, polymalic
acid has been known as a polyhydroxyalkanoate having
a carboxyl group at a side chain thereof. An α -type

represented by the chemical formula (39) and a β -type represented by the chemical formula (40) have been known as polymers of polymalic acid depending on the form of a polymer.



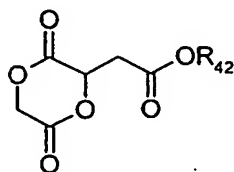
Of those, a polymer obtained by ring-opening polymerization of a benzyl ester of β -malolactone represented by the chemical formula (41) is disclosed in US 4,265,247 (Patent Document 1) as β -type polymalic acid or a copolymer thereof.



(R₄₁: benzyl group.)

In addition, a polymer obtained by copolymerization of a six-membered ring diester monomer represented by the chemical formula (42) and a glycolide or lactide as a cyclic diester or a lactone as an intramolecular ring closure reaction ester of ω -hydroxycarboxylic acid is disclosed in JP-A 02-3415 (Patent Document 2) as a copolymer containing any one of other

hydroxyalkanoic acids typified by α -type polymalic acid-glycolic acid copolymer and glycolic acid.



(42)

(R₄₂ represents a lower alkyl group such as a methyl group, an ethyl group, an n-propyl group, an isopropyl group, or a t-butyl group, or a benzyl group.)

Macromolecules 2000, 33 (13), 4619-4627 (Non-Patent Document 1) discloses that 7-oxo-4-oxepanonecarboxylate is subjected to ring-opening polymerization to produce a polymer having an ester group at a side chain thereof, and the polymer is further subjected to hydrogenolysis to produce a polymer having a carboxylic acid at a side chain thereof as a polyhydroxyalkanoate having a carboxyl group at a side chain thereof. Biomacromolecules 2000, 1, 275 (Non-Patent Document 2) discloses a polymer in which a benzyloxycarbonyl group is introduced into a methylene group at α -position of a carbonyl group in the main-chain of poly(ϵ -caprolactone), the polymer being obtained by: allowing lithium diisopropylamide to react with poly(ϵ -caprolactone); and allowing the resultant to react with benzyl chloroformate. Macromolecular

Bioscience 2004, 4, 232 (Non-Patent Document 3) discloses a polymer in which a (benzyloxycarbonyl)methyl group is introduced into a methylene group at α -position of a carbonyl group in the main chain of polylactic acid, the polymer being
5 obtained by: allowing lithium diisopropylamide to react with polylactic acid; and allowing the resultant to react with benzyl bromoacetate.

Polymeric Materials Science & Engineering 2002,
10 87, 254 (Non-Patent Document 4) discloses, as a polyhydroxyalkanoate having a vinyl group at a side chain thereof, a polymer obtained by ring-opening polymerization of α -allyl(δ -valerolactone). Similarly, Polymer Preprints 2002, 43 (2), 727 (Non-
15 Patent Document 5) discloses, as a polyhydroxyalkanoate having a vinyl group at a side chain thereof, a polymer obtained by ring-opening polymerization of 3,6-diallyl-1,4-dioxane-2,5-dione as a six-membered ring diester monomer.

20 There has been reported a polymer having a new function into which a structure providing functional properties for a polyhydroxyalkanoate into which a chemically modifiable functional group is introduced as described above is introduced. International
25 Journal of Biological Macromolecules 25 (1999) 265 (Non-Patent Document 6) discloses the following. A copolymer of α -type malic acid and glycolic acid is

obtained by ring-opening polymerization of a cyclic dimer of α -type malic acid and glycolic acid, and the resultant polymer is deprotected to obtain a polyester having a carboxyl group at a side chain thereof. Tripeptide is chemically modified to the carboxyl group at the side chain, and the resultant polymer is evaluated for cell adhesion. At this time, a good result is obtained.

10 DISCLOSURE OF THE INVENTION

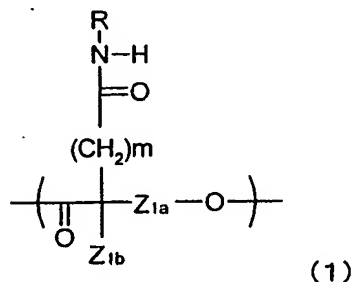
It may be possible that new functional properties can be provided by introducing a unit having a carboxyl group that is a reactive functional group, in a molecule as described above; and chemically modifying the reactive functional group. However, there have been a small number of reports concerning it. In view of the above, the present invention provides: a novel polyhydroxyalkanoate having a reactive functional group in a molecule and a method of producing the same; and a novel polyhydroxyalkanoate having a new function obtained by chemically modifying the polyhydroxyalkanoate having a reactive functional group and a method of producing the same.

25 The inventors of the present invention have made extensive studies with a view to developing a novel polyhydroxyalkanoate having a reactive

functional group in a molecule and a novel
polyhydroxyalkanoate having a new function obtained
by chemically modifying the polyhydroxyalkanoate
having a reactive functional group, thereby
5 completing the invention described below.

The polyhydroxyalkanoate according to the
present invention includes the following.

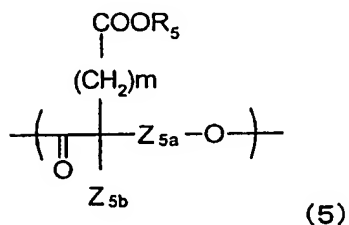
(1) A polyhydroxyalkanoate, comprising one or
more units each represented by the chemical formula
10 (1).



(In the formula, R represents $-\text{A}_1-\text{SO}_2\text{R}_1$. R_1 represents
OH, a halogen atom, ONa, OK, or OR_{1a} . R_{1a} and A_1 each
independently represent a group having a substituted
15 or unsubstituted aliphatic hydrocarbon structure, a
substituted or unsubstituted aromatic ring structure,
or a substituted or unsubstituted heterocyclic
structure. Z_{1a} represents a linear alkylene chain
having 1 to 4 carbon atoms. The linear alkylene
20 chain has at least one linear or branched alkyl group,
or at least one alkyl group containing a residue
having any one of a phenyl structure, a thienyl
structure, and a cyclohexyl structure at a terminal

thereof. Z_{1b} represents a hydrogen atom, a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. In addition, m represents an integer selected from 0 to 8. When multiple units exist, R , R_1 , R_{1a} , A_1 , Z_{1a} , Z_{1b} , and m each independently have the above meaning for each unit.)

(2) A polyhydroxyalkanoate, comprising one or more units each represented by the chemical formula (5).

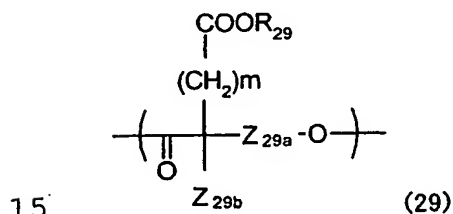


(In the formula, R_5 represents hydrogen, a group for forming a salt, or R_{5a} . R_{5a} represents a linear or branched alkyl or aralkyl group having 1 to 12 carbon atoms, or a group having a saccharide. m represents an integer selected from 0 to 8. Z_{5a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{5b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted

by an aryl group. When multiple units exist, R_5 , R_{5a} , Z_{5a} , Z_{5b} , and m each independently have the above meaning for each unit.)

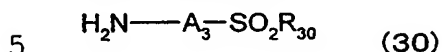
On the other hand, the method of producing
 5 polyhydroxyalkanoate according to the present invention includes the following.

(A) A method of producing a polyhydroxyalkanoate containing a unit represented by the chemical formula (1), characterized by comprising
 10 the step of subjecting a polyhydroxyalkanoate containing a unit represented by the chemical formula (29) and at least one kind of amine compound represented by the chemical formula (30) to a condensation reaction.

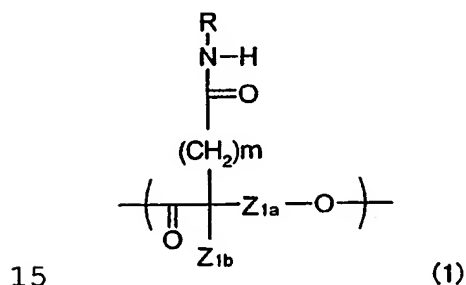


(In the formula, R_{29} represents hydrogen or a group for forming a salt. m represents an integer selected from 0 to 8. Z_{29a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene
 20 chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{5b} represents a hydrogen atom, or a linear

or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, R_{29} , Z_{29a} , Z_{29b} , and m each independently have the above meaning for each unit.)



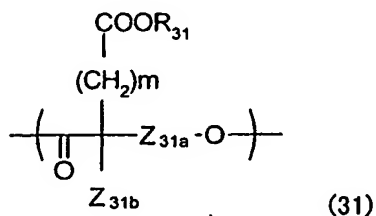
(In the formula, R_{30} represents OH, a halogen atom, ONa, OK, or OR_{30a} . R_{30a} and A_3 each independently represent a group having a substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, or a substituted or unsubstituted heterocyclic structure. When multiple units exist, R_{30} , R_{30a} , and A_3 , and m each independently have the above meaning for each unit.)



(In the formula, R represents $-A_1-SO_2R_1$. R_1 represents OH, a halogen atom, ONa, OK, or OR_{1a} . R_{1a} and A_1 each independently represent a group having a substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, or a substituted or unsubstituted heterocyclic structure. Z_{1a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene

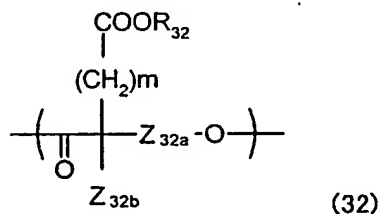
chain has at least one linear or branched alkyl group,
 or at least one alkyl group containing a residue
 having any one of a phenyl structure, a thienyl
 structure, and a cyclohexyl structure at a terminal
 5 thereof. Z_{1b} represents a hydrogen atom, or a linear
 or branched alkyl group, aryl group, or aralkyl group
 which may be substituted by an aryl group. In
 addition, m represents an integer selected from 0 to
 8. When multiple units exist, R , R_1 , R_{1a} , A_1 , Z_{1a} , Z_{1b} ,
 10 and m each independently have the above meaning for
 each unit.)

(B) A method of producing a
 polyhydroxyalkanoate containing a unit represented by
 the chemical formula (32), characterized by
 15 comprising the step of hydrolyzing a
 polyhydroxyalkanoate containing a unit represented by
 the chemical formula (31) in the presence of an acid
 or an alkali, or the step of subjecting the
 polyhydroxyalkanoate to hydrogenolysis including
 20 catalytic reduction.



(In the formula, R_{31} represents a linear or branched
 alkyl or aralkyl group having 1 to 12 carbon atoms.
 Z_{31a} represents a linear alkylene chain having 1 to 4

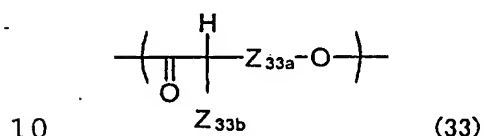
carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{31b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. In addition, m represents an integer selected from 0 to 8. When multiple units exist, R_{31} , Z_{31a} , Z_{31b} , and m each independently have the above meaning for each unit.)



(In the formula, R_{32} represents hydrogen or a group for forming a salt. Z_{32a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{32b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. m represents an integer selected from 0 to 8. When multiple units exist, R_{32} , Z_{32a} , Z_{32b} , and m each

independently have the above meaning for each unit.)

(C) A method of producing a polyhydroxyalkanoate containing a unit represented by the chemical formula (35), characterized by including the steps of: allowing a polyhydroxyalkanoate containing a unit represented by the chemical formula (33) to react with a base; and allowing the compound obtained in the foregoing step to react with a compound represented by the chemical formula (34).

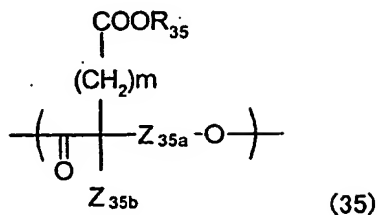


(In the formula, Z_{33a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{33b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, Z_{33a} and Z_{33b} each independently have the above meaning for each unit.)



(In the formula, m represents an integer selected from 0 to 8. X represents a halogen atom. R_{34} represents a linear or branched alkyl or aralkyl

group having 1 to 12 carbon atoms.)

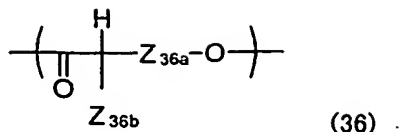


(In the formula, R_{35} represents a linear or branched alkyl or aralkyl group having 1 to 12 carbon atoms.

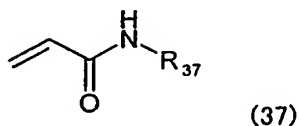
- 5 Z_{35a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a
- 10 cyclohexyl structure at a terminal thereof. Z_{35b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. In addition, m represents an integer selected from 0 to 8. When
- 15 multiple units exist, R_{35} , Z_{35a} , Z_{35b} , and m each independently have the above meaning for each unit.)

(D) A method of producing a polyhydroxyalkanoate containing a unit represented by the chemical formula (38), characterized by including

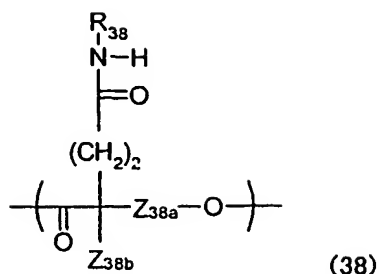
20 the steps of: allowing a polyhydroxyalkanoate containing a unit represented by the chemical formula (36) to react with a base; and allowing the compound obtained in the foregoing step to react with a compound represented by the chemical formula (37).



(In the formula, Z_{36a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{36b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, Z_{36a} and Z_{36b} each independently have the above meaning for each unit.)



(In the formula, R_{37} represents $-\text{A}_{37}-\text{SO}_2\text{R}_{37a}$. R_{37a} represents OH, a halogen atom, ONa, OK, or OR_{37b} . R_{37b} and A_{37} are each independently selected from groups each having a substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, or a substituted or unsubstituted heterocyclic structure. When multiple units exist, R_{37} , R_{37a} , R_{37b} , and A_{37} each independently have the above meaning for each unit.)



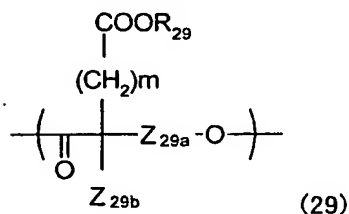
(In the formula, R_{38} represents $-A_{38}-SO_2R_{38a}$. R_{38a} represents OH, a halogen atom, ONa, OK, or OR_{38b} . R_{38b} and A_{38} each independently represent a group having a substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, or a substituted or unsubstituted heterocyclic structure. Z_{38a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{38b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, R_{38} , R_{38a} , R_{38b} , A_{38} , Z_{38a} , and Z_{38b} each independently have the above meaning for each unit.)

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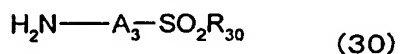
BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, the contents of the present invention will be described. A polyhydroxyalkanoate

containing a unit represented by the chemical formula (1) as a target in the present invention can be produced by a reaction between a polyhydroxyalkanoate containing a unit represented by the chemical formula (29) to be used as a starting material and at least one kind of aminosulfonic acid compound represented by the chemical formula (30).



(In the formula, R_{29} represents hydrogen or a group for forming a salt. m represents an integer selected from 0 to 8. Z_{29a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{29b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, R_{29} , Z_{29a} , Z_{29b} , and m each independently have the above meaning for each unit.)

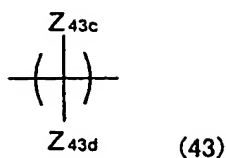


(In the formula, R_{30} represents OH, a halogen atom, ONa, OK, or OR_{30a} . R_{30a} and A_3 are each independently

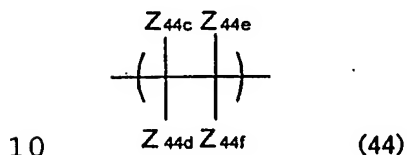
selected from groups each having a substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, or a substituted or unsubstituted heterocyclic structure (R_{30a} represents a monovalent group having a structure selected from them, and A₃ represents a divalent group having a structure selected from them). When multiple units exist, R₃₀, R_{30a}, and A₃ each independently have the above meaning for each unit.)

10 More specifically, in the compound represented by the chemical formula (29) to be used in the present invention, Z₂₉ represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a
15 residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. The linear alkylene chain structure represented by Z₂₉ is preferably selected
20 from the following (A) to (D).

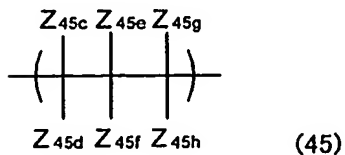
(A) When the linear alkylene chain has 1 carbon atom, in the linear alkylene chain structure represented by the chemical formula (43), one of Z_{43c} and Z_{43d} represents a linear or branched alkyl group,
25 or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



(B) When the linear alkylene chain has 2 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (44), one of Z_{44c} , Z_{44d} , Z_{44e} , and Z_{44f} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.

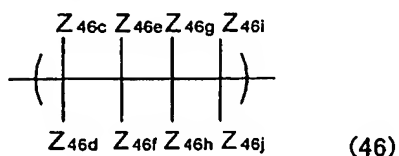


(C) When the linear alkylene chain has 3 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (45), one of Z_{45c} , Z_{45d} , Z_{45e} , Z_{45f} , Z_{45g} , and Z_{45h} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.

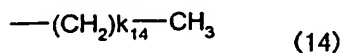


(D) When the linear alkylene chain has 4 carbon atoms, in the linear alkylene chain structure

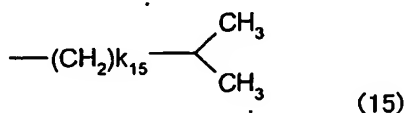
represented by the chemical formula (46), one of Z_{46c}, Z_{46d}, Z_{46e}, Z_{46f}, Z_{46g}, Z_{46h}, Z_{46i}, and Z_{46j} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



When a substituent selected from Z_{43c}, Z_{43d}, Z_{44c}, Z_{44d}, Z_{44e}, Z_{44f}, Z_{45c}, Z_{45d}, Z_{45e}, Z_{45f}, Z_{45g}, Z_{45h}, Z_{46c}, Z_{46d}, Z_{46e}, Z_{46f}, Z_{46g}, Z_{46h}, Z_{46i}, and Z_{46j} described in the chemical formulae (43), (44), (45), and (46) represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof, the substituent is more preferably selected from substituents represented by the chemical formulae (14), (15), (16), and (17).

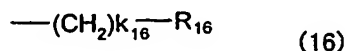


(In the formula, k₁₄ represents an integer selected from 0 to 8. When multiple units exist, k₁₄'s each independently have the above meaning for each unit.)

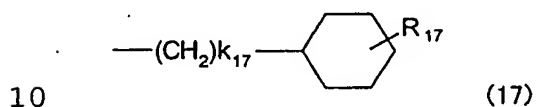


(In the formula, k₁₅ represents an integer selected

from 0 to 7. When multiple units exist, k_{15} 's each independently have the above meaning for each unit.)



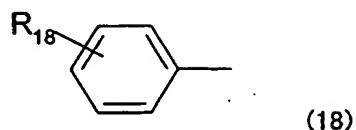
(In the formula, k_{16} represents an integer selected from 1 to 8. R_{16} represents a substituent containing a residue having any one of a phenyl structure and a thienyl structure. When multiple units exist, k_{15} and R_{16} each independently have the above meaning for each unit.)



(In the formula, R_{17} represents a substituent to a cyclohexyl group selected from an H atom, a CN group, an NO_2 group, a halogen atom, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. k_{17} represents an integer selected from 0 to 8. When multiple units exist, k_{17} and R_{17} each independently have the above meaning for each unit.)

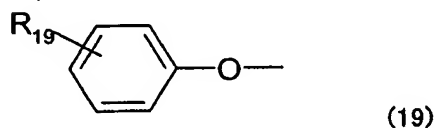
In addition, R_{16} in the chemical formula (16), that is, a residue having any one of a phenyl structure and a thienyl structure is selected from the group of residues represented by the chemical formulae (18), (19), (20), (21), (22), (23), (24), (25), (26), (27), and (28).

Here, the chemical formula (18) represents a group of unsubstituted or substituted phenyl groups.



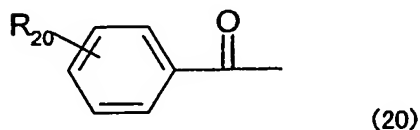
(In the formula, R_{18} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $\text{CH}=\text{CH}_2$ group, COOR_{18a} (R_{18a} represents an H atom, an Na atom, or a K atom.), a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{18} 's may be different for each unit.)

The chemical formula (19) represents a group of unsubstituted or substituted phenoxy groups.



(In the formula, R_{19} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a SCH_3 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{19} 's may be different for each unit.)

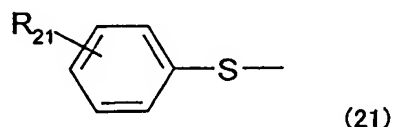
The chemical formula (20) represents a group of unsubstituted or substituted benzoyl groups.



(In the formula, R_{20} represents a substituent to an

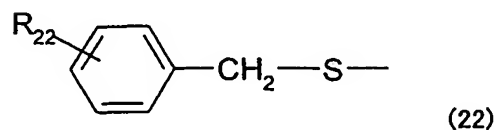
aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₂₀'s may be different for each unit.)

The chemical formula (21) represents a group of unsubstituted or substituted phenylsulfanyl groups.



(In the formula, R₂₁ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{21a}, SO₂R_{21b} (R_{21a} represents H, Na, K, CH₃, or C₂H₅, and R_{21b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₁'s may be different for each unit.)

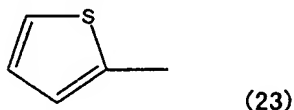
The chemical formula (22) represents a group of unsubstituted or substituted (phenylmethyl)sulfanyl groups.



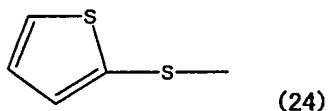
(In the formula, R₂₂ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{22a}, SO₂R_{22b} (R_{22a}

represents H, Na, K, CH₃, or C₂H₅, and R_{22b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₂'s
 5 may be different for each unit.)

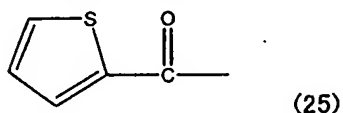
The chemical formula (23) represents a 2-thienyl group.



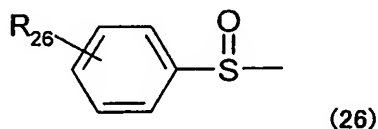
The chemical formula (24) represents a 2-thienylsulfanyl group.
 10



The chemical formula (25) represents a 2-thienylcarbonyl group.



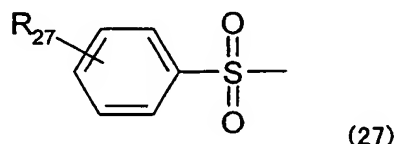
The chemical formula (26) represents a group of unsubstituted or substituted phenylsulfinyl groups.
 15



(In the formula, R₂₆ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{26a}, SO₂R_{26b} (R_{26a}
 20 represents H, Na, K, CH₃, or C₂H₅, and R_{26b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃

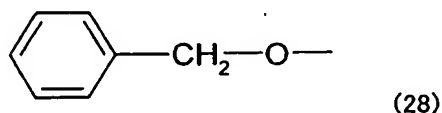
group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₆'s may be different for each unit.)

The chemical formula (27) represents a group of
5 unsubstituted or substituted phenylsulfonyl groups.



(In the formula, R₂₇ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{27a}, SO₂R_{27b} (R_{27a}
10 represents H, Na, K, CH₃, or C₂H₅, and R_{27b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₇'s may be different for each unit.)

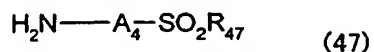
15 The chemical formula (28) represents a (phenylmethyl)oxy group.



On the other hand, in the compound represented by the chemical formula (30) to be used in the
20 present invention, R₃₀ represents OH, a halogen atom, ONa, OK, or OR₃₀. R₃₀ represents a linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group.

A₃ represents a liner or branched and substituted or unsubstituted alkylene group having 1 to 8 carbon atoms, a substituted or unsubstituted phenylene group, a substituted or unsubstituted naphthalene group, or a substituted or unsubstituted heterocyclic structure containing one or more of N, S, and O. When A₃ represents a ring structure, an unsubstituted ring may be further condensed. In addition, when multiple units exist, R₃₀, R_{30a}, and A₃ each independently have the above meaning for each unit.

When A₃ represents a linear and substituted or unsubstituted alkylene group, an aminosulfonic acid compound represented by the following chemical formula (47) is exemplified.

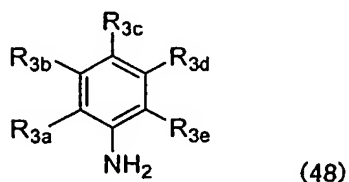


(In the formula, R₄₇ represents OH, a halogen atom, ONa, OK, or OR_{47a}. R_{47a} represents a linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group. A₄ represents a liner or branched and substituted or unsubstituted alkylene group having 1 to 8 carbon atoms, which may be substituted by an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, or the like as a substituent.)

Examples of the compound represented by the chemical formula (47) include 2-aminoethanesulfonic

acid (taurine), 3-aminopropanesulfonic acid, 4-aminobutanesulfonic acid, 2-amino-2-methylpropanesulfonic acid, and alkali metal salts and esterified products thereof.

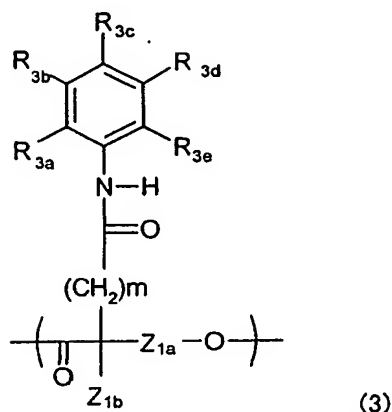
- 5 When A_3 represents a substituted or unsubstituted phenylene group, an aminosulfonic acid compound represented by the following chemical formula (48) is exemplified.



- 10 (In the formula, R_{3a} , R_{3b} , R_{3c} , R_{3d} , and R_{3e} each independently represent SO_2R_{3f} (R_{3f} represents OH, a halogen atom, ONa, OK, or OR_{3f1} . (R_{3f1} represents a linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group.)), a hydrogen atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an OH group, an NH_2 group, an NO_2 group, $COOR_{3g}$ (R_{3g} represents an H atom, an Na atom, or a K atom.), an acetamide group, an OPh group, an NHPH-group, a CF_3 group, a C_2F_5 group, or a C_3F_7 group (Ph represents a phenyl group.), and at least one of these groups represents SO_2R_{3f} .)

A polyhydroxyalkanoate having one or more units each represented by the chemical formula (3) can be

obtained by using a compound represented by the chemical formula (48).

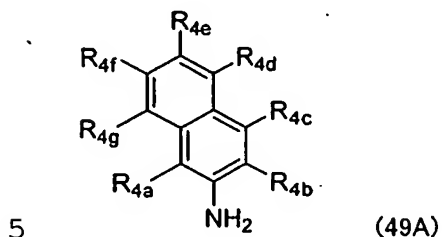


(In the formula, R_{3a} , R_{3b} , R_{3c} , R_{3d} , and R_{3e} each
 5 independently represent SO_2R_{3f} (R_{3f} represents OH, a
 halogen atom, ONa, OK, or OR_{3f1} . (R_{3f1} represents a
 linear or branched alkyl group having 1 to 8 carbon
 atoms, or a substituted or unsubstituted phenyl
 group.)), a hydrogen atom, a halogen atom, an alkyl
 10 group having 1 to 20 carbon atoms, an alkoxy group
 having 1 to 20 carbon atoms, an OH group, an NH_2
 group, an NO_2 group, $COOR_{3g}$ (R_{3g} represents an H atom,
 an Na atom, or a K atom.), an acetamide group, an OPh
 group, an NHPh group, a CF_3 group, a C_2F_5 group, or a
 15 C_3F_7 group (Ph represents a phenyl group.), and at
 least one of these groups represents SO_2R_{3f} . Z_{3a}
 represents a linear alkylene chain having 1 to 4
 carbon atoms. The linear alkylene chain has at least
 one linear or branched alkyl group, or at least one
 20 alkyl group containing a residue having any one of a

phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{3b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. In addition, m represents an integer selected from 0 to 8. When multiple units exist, R_{3a} , R_{3b} , R_{3c} , R_{3d} , R_{3e} , R_{3f} , R_{3f1} , R_{3g} , Z_{1a} , Z_{1b} , and m each independently have the above meaning for each unit.)

10 Examples of the compound represented by the chemical formula (48) include p-aminobenzenesulfonic acid (sulfanilic acid), m-aminobenzenesulfonic acid, o-aminobenzenesulfonic acid, m-toluidine-4-sulfonic acid, sodium o-toluidine-4-sulfonate, p-toluidine-2-
15 sulfonic acid, 4-methoxyaniline-2-sulfonic acid, o-anisidine-5-sulfonic acid, p-anisidine-3-sulfonic acid, 3-nitroaniline-4-sulfonic acid, sodium 2-nitroaniline-4-sulfonate, sodium 4-nitroaniline-2-sulfonate, 1,5-dinitroaniline-4-sulfonic acid, 2-
20 aminophenol-4-hydroxy-5-nitrobenzenesulfonic acid, sodium 2,4-dimethylaniline-5-sulfonate, 2,4-dimethylaniline-6-sulfonic acid, 3,4-dimethylaniline-5-sulfonic acid, 4-isopropylaniline-6-sulfonic acid, 4-trifluoromethylaniline-6-sulfonic acid, 3-carboxy-
25 4-hydroxyaniline-5-sulfonic acid, 4-carboxyaniline-6-sulfonic acid, and alkali metal salts and esterified products thereof.

When A₃ represents a substituted or unsubstituted naphthalene group, an aminosulfonic acid compound represented by the following chemical formula (49A) or (49B) is exemplified.



(In the formula, R_{4a}, R_{4b}, R_{4c}, R_{4d}, R_{4e}, R_{4f}, and R_{4g} each independently represent SO₂R_{4o} (R_{4o} represents OH, a halogen atom, ONa, OK, or OR_{4o1}. (R_{4o1} represents a linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group.)), a hydrogen atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an OH group, an NH₂ group, an NO₂ group, COOR_{4p} (R_{4p} represents an H atom, an Na atom, or a K atom.), an acetamide group, an OPh group, an NHPPh group, a CF₃ group, a C₂F₅ group, or a C₃F₇ group (Ph represents a phenyl group.), and at least one of these groups represents SO₂R_{4o}.)

10

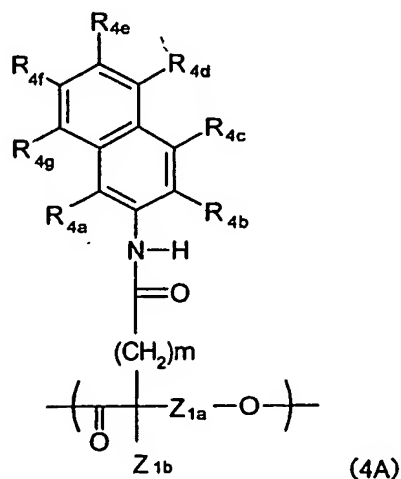
15



20 (In the formula, R_{4h}, R_{4i}, R_{4j}, R_{4k}, R_{4l}, R_{4m}, and R_{4n}

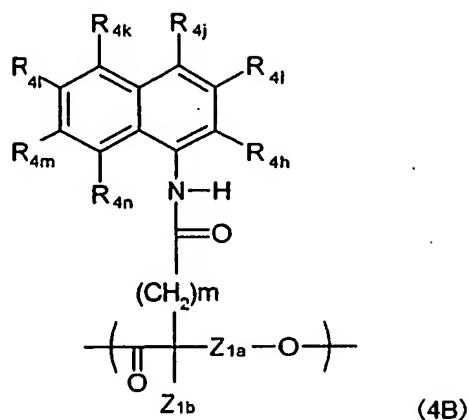
each independently represent SO_2R_{40} (R_{40} represents OH, a halogen atom, ONa, OK, or OR_{401} . (R_{401} represents a linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group.)), a hydrogen atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an OH group, an NH_2 group, an NO_2 group, COOR_{4p} (R_{4p} represents an H atom, an Na atom, or a K atom.), an acetamide group, an OPh group, an NHPH group, a CF_3 group, a C_2F_5 group, or a C_3F_7 group (Ph represents a phenyl group.), and at least one of these groups represents SO_2R_{40} .)

A polyhydroxyalkanoate having one or more units each represented by the chemical formula (4A) or (4B) can be obtained by using a compound represented by the chemical formula (49A) or (49B).



(In the formula, R_{4a} , R_{4b} , R_{4c} , R_{4d} , R_{4e} , R_{4f} , and R_{4g} each independently represent SO_2R_{40} (R_{40} represents OH,

a halogen atom, ONa, OK, or OR_{4o1}. (R_{4o1} represents a linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group.)), a hydrogen atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an OH group, an NH₂ group, an NO₂ group, COOR_{4p} (R_{4p} represents an H atom, an Na atom, or a K atom.), an acetamide group, an OPh group, an NPh group, a CF₃ group, a C₂F₅ group, or a C₃F₇ group (Ph represents a phenyl group.), and at least one of these groups represents SO₂R_{4o}. Z_{1a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{1b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. In addition, m represents an integer selected from 0 to 8. When multiple units exist, R_{4a}, R_{4b}, R_{4c}, R_{4d}, R_{4e}, R_{4f}, R_{4g}, R_{4o}, R_{4o1}, R_{4p}, m, Z_{1a}, Z_{1b}, and n each independently have the above meaning for each unit.)



(In the formula, R_{4h} , R_{4i} , R_{4j} , R_{4k} , R_{4l} , R_{4m} , and R_{4n} each independently represent SO_2R_{4o} (R_{4o} represents OH, a halogen atom, ONa, OK, or OR_{4o1} . (R_{4o1} represents a
 5 linear or branched alkyl group having 1 to 8 carbon atoms, or a substituted or unsubstituted phenyl group.)), a hydrogen atom, a halogen atom, an alkyl group having 1 to 20 carbon atoms, an alkoxy group having 1 to 20 carbon atoms, an OH group, an NH_2
 10 group, an NO_2 group, $COOR_{4p}$ (R_{4p} represents an H atom, an Na atom, or a K atom.), an acetamide group, an OPh group, an NPh group, a CF_3 group, a C_2F_5 group, or a C_3F_7 group (Ph represents a phenyl group.), and at least one of these groups represents SO_2R_{4o} . In
 15 addition, m represents an integer selected from 0 to 8. Z_{1a} represents ~~a linear~~ alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one
 20 of a phenyl structure, a thienyl structure, and a

cyclohexyl structure at a terminal thereof. Z_{1b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units
5 exist, R_{4h}, R_{4i}, R_{4j}, R_{4k}, R_{4l}, R_{4m}, R_{4n}, R_{4o}, R_{4ol}, R_{4p}, Z_{1a}, Z_{1b}, and m each independently have the above meaning for each unit.)

Examples of the compound represented by the chemical formula (49A) or (49B) include: sulfonic
10 acids such as 1-naphthylamine-5-sulfonic acid, 1-naphthylamine-4-sulfonic acid, 1-naphthylamine-8-sulfonic acid, 2-naphthylamine-5-sulfonic acid, 1-naphthylamine-6-sulfonic acid, 1-naphthylamine-7-sulfonic acid, 1-naphthylamine-2-ethoxy-6-sulfonic
15 acid, 1-amino-2-naphthol-4-sulfonic acid, 6-amino-1-naphthol-3-sulfonic acid, sodium 1-amino-8-naphthol-2,4-sulfonate, sodium 1-amino-8-naphthol-3,6-sulfonate; and alkali metal salts and esterified products of the sulfonic acids.

20 When A₃ represents a substituted or unsubstituted heterocyclic structure containing one or more of N, S, and O, A₃ may represent any one of a pyridine ring, a piperazine ring, a furan ring, and a thiol ring as a heterocyclic ring. Examples of such
25 a compound include: sulfonic acids such as 2-aminopyridine-6-sulfonic acid and 2-aminopiperazine-6-sulfonic acid; and alkali metal salts and

esterified products of the sulfonic acids.

As described above, examples of a group forming an ester bond with a sulfonic acid in the case of a sulfonate include a group containing a substituted or
5 unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, and a substituted or unsubstituted heterocyclic structure. Furthermore, a linear or branched alkyl group having 1 to 8 carbon atoms, a substituted or
10 unsubstituted phenyl group, or the like is preferable. From the viewpoint of, for example, ease of esterification, one having a group such as OCH_3 , OC_2H_5 , OC_6H_5 , OC_3H_7 , OC_4H_9 , $\text{OCH}(\text{CH}_3)_2$, $\text{OCH}_2\text{C}(\text{CH}_3)_3$, or $\text{OC}(\text{CH}_3)_3$ is more preferable.

15 (Method of producing polyhydroxyalkanoate having unit represented by chemical formula (1))

A reaction between a polyhydroxyalkanoate containing a unit represented by the chemical formula (29) and an aminosulfonic acid compound represented
20 by the chemical formula (30) in the present invention will be described in detail.

The amount of the compound represented by the chemical formula (30) to be used in the present invention is in the range of 0.1 to 50.0 times mole,
25 or preferably 1.0 to 20.0 times mole with respect to the unit represented by the chemical formula (29) to be used as a starting material. An example of a

method of producing an amide bond from a carboxylic acid and an amine in the present invention includes a condensation reaction by virtue of heat dehydration. In particular, from the viewpoint of achieving a mild
5 reaction condition under which an ester bond of a polymer main chain is not cleaved, a method is effective, which involves: activating a carboxylic acid portion with an activator to produce an active acyl intermediate; and allowing the intermediate to
10 react with an amine. Examples of the active acyl intermediate include an acid halide, an acid anhydride, and an active ester. In particular, a method of forming an amide bond in an identical reaction field by using a condensing agent is
15 preferable from the viewpoint of simplifying a production process.

If required, the active acyl intermediate may be isolated as an acid halide before being subjected to a condensation reaction with an amine.

20 A phosphoric acid-based condensing agent used for polycondensation of an aromatic polyamide, a carbodiimide-based condensing agent used for synthesizing a peptide, an acid chloride-based condensing agent, or the like can be appropriately
25 selected as a condensing agent to be used depending on the combination of the chemical formulae (30) and (29).

Examples of the phosphoric acid-based
condensing agent include a phosphite-based condensing
agent, a phosphorus chloride-based condensing agent,
a phosphoric anhydride-based condensing agent, a
5 phosphate-based condensing agent, and a phosphoric
amide-based condensing agent.

A phosphite-based condensing agent or the like
can be used in the reaction of the present invention.
Examples of a phosphite used at this time include
10 triphenyl phosphite, diphenyl phosphite, tri-o-tolyl
phosphite, di-o-tolyl phosphite, tri-m-tolyl
phosphite, di-m-tolyl phosphite, tri-p-tolyl
phosphite, di-p-tolyl phosphite, di-o-chlorophenyl
phosphite, tri-p-chlorophenyl phosphite, di-p-
15 chlorophenyl phosphite, trimethyl phosphite, and
triethyl phosphite. Of those, triphenyl phosphite is
preferably used. A metal salt such as lithium
chloride or calcium chloride may be added for
improving the solubility, reactivity, and the like of
20 a polymer.

Examples of the carbodiimide-based condensing
agent include dicyclohexyl carbodiimide (DCC), N-
ethyl-N'-3-dimethylaminopropyl carbodiimide
(EDC=WSCI), and diisopropyl carbodiimide (DIPC). DCC
25 or WSCI may be used in combination with N-
hydroxysuccinimide (HONSu), 1-hydroxybenzotriazole
(HOBt), 3-hydroxy-4-oxo-3,4-dihydro-1,2,3-

benzotriazine (HOObt), or the like.

The amount of the condensing agent to be used is in the range of 0.1 to 50 times mole, or preferably 1 to 20 times mole with respect to the
5 compound represented by the chemical formula (29).

A solvent may be used as required in the reaction of the present invention. Examples of an available solvent include: hydrocarbons such as hexane, cyclohexane, and heptane; ketones such as
10 acetone and methyl ethyl ketone; ethers such as dimethyl ether, diethyl ether, and tetrahydrofuran; halogenated hydrocarbons such as dichloromethane, chloroform, carbon tetrachloride, dichloroethane, and trichloroethane; aromatic hydrocarbons such as
15 benzene and toluene; aprotic polar solvents such as N,N-dimethylformamide, dimethyl sulfoxide, dimethyl acetamide, and hexamethylphosphoramide; pyridine derivatives such as pyridine and picoline; and N-methylpyrrolidone. Pyridine, N-methylpyrrolidone, or
20 the like is particularly preferably used. The amount of the solvent to be used can be appropriately determined in accordance with kinds of a starting material and a base, a reaction condition, and the like.

25 A reaction temperature is not particularly limited in the method of the present invention, but is generally in the range of -20°C to the boiling

point of a solvent. However, it is preferable to perform the reaction at an optimum temperature suited for a condensing agent to be used.

In the method of the present invention, a
5 reaction time is generally in the range of 1 to 48 hours. The reaction time is particularly preferably in the range of 1 to 10 hours.

A thus produced reaction solution containing a polyhydroxyalkanoate having a unit represented by the
10 chemical formula (1) in the present invention can be collected and purified by, for example, distillation as an ordinary method. Alternatively, the reaction solution can be collected by mixing a solvent (for example, water, an alcohol such as methanol or
15 ethanol, or an ether such as dimethyl ether, diethyl ether, or tetrahydrofuran) evenly with the reaction solution; and reprecipitating a target polyhydroxyalkanoate having a unit represented by the chemical formula (1). The resultant
20 polyhydroxyalkanoate having a unit represented by the chemical formula (1) can be subjected to isolation purification as required. A method for the isolation purification is ~~not~~ particularly limited, and a method involving reprecipitation using a solvent
25 insoluble in the polyhydroxyalkanoate represented by the chemical formula (1), a method according to column chromatography, dialysis, or the like can be

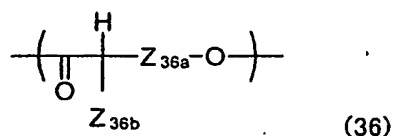
used.

When an R portion in the chemical formula (1) is $-A_1-SO_3H$, a method can be adopted as another production method of the present invention, which involves methyl esterifying the R portion in the chemical formula (1) into $-A_1-SO_3CH_3-$ using a methyl-esterifying agent after a condensation reaction with an amine. Examples of an available methyl-esterifying agent include those used for methyl esterification of an aliphatic acid in gas chromatography. Examples of a methyl esterification method include: acid catalyst methods such as a hydrochloric acid-methanol method, a boron trifluoride-methanol method, and a sulfuric acid-methanol method; and base catalyst methods such as a sodium methoxide method, a tetramethylguanidine method, and a trimethylsilyldiazomethane method. Of those, a trimethylsilyldiazomethane method is preferable because methylation can be performed under a moderate condition.

Examples of a solvent to be used in the reaction of the present invention include: hydrocarbons such as hexane, cyclohexane, and heptane; alcohols such as methanol and ethanol; halogenated hydrocarbons such as dichloromethane, chloroform, carbon tetrachloride, dichloroethane, and trichloroethane; and aromatic hydrocarbons such as

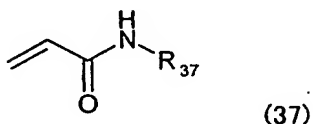
benzene and toluene. Halogenated hydrocarbons and the like are particularly preferably used. The amount of the solvent to be used can be appropriately determined in accordance with a starting material, a
 5 reaction condition, and the like. A reaction temperature is not particularly limited in the method of the present invention, but is generally in the range of -20°C to 30°C. However, it is preferable to perform the reaction at an optimum temperature suited
 10 for a condensing agent and a reagent to be used.

In addition, in the present invention, a polyhydroxyalkanoate containing a unit represented by the chemical formula (38) can be produced through the steps of: allowing a polyhydroxyalkanoate having a
 15 unit represented by the chemical formula (36) to react with a base; and allowing the compound obtained in the foregoing step to react with a compound represented by the chemical formula (37).

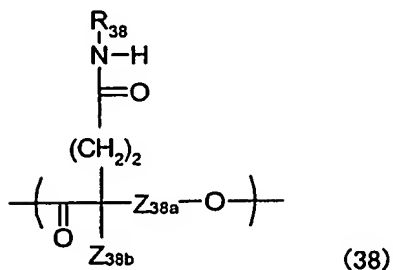


20 (In the formula, Z_{36a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a
 25 thienyl structure, and a cyclohexyl structure at a

terminal thereof. Z_{36b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, Z_{36a} and Z_{36b} each
 5 independently have the above meaning for each unit.)



(In the formula, R_{37} represents $-\text{A}_{37}-\text{SO}_2\text{R}_{37a}$. R_{37a} represents OH, a halogen atom, ONa, OK, or OR_{37b} . R_{37b} and A_{37} are each independently selected from groups
 10 each having a substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic ring structure, or a substituted or unsubstituted heterocyclic structure. When multiple units exist, R_{37} , R_{37a} , R_{37b} , and A_{37} each independently
 15 have the above meaning for each unit.)



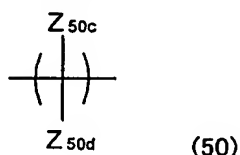
(In the formula, R_{38} represents $-\text{A}_{38}-\text{SO}_2\text{R}_{38a}$. R_{38a} represents OH, a halogen atom, ONa, OK, or OR_{38b} . R_{38b} and A_{38} each independently represent a group having a
 20 substituted or unsubstituted aliphatic hydrocarbon structure, a substituted or unsubstituted aromatic

ring structure, or a substituted or unsubstituted heterocyclic structure. Z_{38a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or
5 branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{38b} represents a hydrogen atom, or a linear or branched alkyl group,
10 aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, R_{38} , R_{38a} , R_{38b} , A_{38} , Z_{38a} , and Z_{38b} each independently have the above meaning for each unit.)

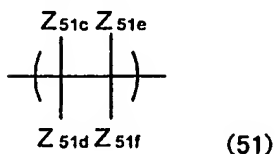
More specifically, in the compound represented
15 by the chemical formulae (36) and (38) to be used in the present invention, Z_{36a} and Z_{38a} each represent a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain is arbitrarily substituted by at least one linear or branched alkyl group, or at
20 least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. The linear alkylene chain structure represented by each of Z_{36a} and Z_{38a} is preferably selected from the
25 following (A) to (D).

(A) When the linear alkylene chain has 1 carbon atom, in the linear alkylene chain structure

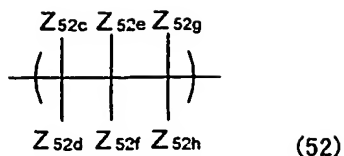
represented by the chemical formula (50), one of Z_{50c}
 and Z_{50d} represents a linear or branched alkyl group,
 or an alkyl group containing a residue having any one
 of a phenyl structure, a thienyl structure, and a
 5 cyclohexyl structure at a terminal thereof.



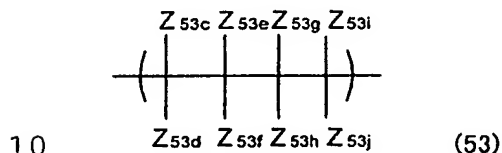
(B) When the linear alkylene chain has 2 carbon
 atoms, in the linear alkylene chain structure
 represented by the chemical formula (51), one of Z_{51c},
 10 Z_{51d}, Z_{51e}, and Z_{51f} represents a linear or branched
 alkyl group, or an alkyl group containing a residue
 having any one of a phenyl structure, a thienyl
 structure, and a cyclohexyl structure at a terminal
 thereof.



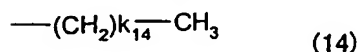
(C) When the linear alkylene chain has 3 carbon
 atoms, in the linear alkylene chain structure
 represented by the chemical formula (52), one of Z_{52c},
 Z_{52d}, Z_{52e}, Z_{52f}, Z_{52g}, and Z_{52h} represents a linear or
 20 branched alkyl group, or an alkyl group containing a
 residue having any one of a phenyl structure, a
 thienyl structure, and a cyclohexyl structure at a
 terminal thereof.



(D) When the linear alkylene chain has 4 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (53), one of Z_{53c}, Z_{53d}, Z_{53e}, Z_{53f}, Z_{53g}, Z_{53h}, Z_{53i}, and Z_{53j} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.

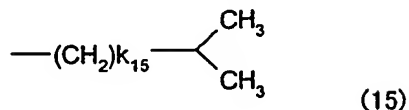


When a substituent selected from Z_{50c}, Z_{50d}, Z_{51c}, Z_{51d}, Z_{51e}, Z_{51f}, Z_{52c}, Z_{52d}, Z_{52e}, Z_{52f}, Z_{52g}, Z_{52h}, Z_{53c}, Z_{53d}, Z_{53e}, Z_{53f}, Z_{53g}, Z_{53h}, Z_{53i}, and Z_{53j} described in the chemical formulae (50), (51), (52), and (53) represents an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof, the substituent is more preferably selected from substituents represented by the chemical formulae (14), (15), (16), and (17).

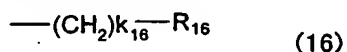


(In the formula, k₁₄ represents an integer selected from 0 to 8. When multiple units exist, k₁₄'s each

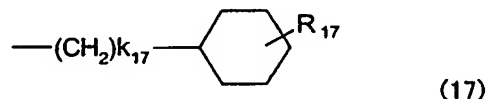
independently have the above meaning for each unit.)



(In the formula, k_{15} represents an integer selected from 0 to 7. When multiple units exist, k_{15} 's each
5 independently have the above meaning for each unit.)



(In the formula, k_{16} represents an integer selected from 1 to 8. R_{16} represents a substituent containing a residue having any one of a phenyl structure and a
10 thienyl structure. When multiple units exist, k_{16} and R_{16} each independently have the above meaning for each unit.)

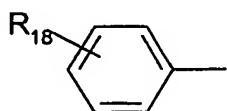


(In the formula, R_{17} represents a substituent to a
15 cyclohexyl group selected from an H atom, a CN group, an NO_2 group, a halogen atom, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. k_{17} represents an integer selected from 0 to 8. When multiple units exist, k_{17} and R_{17} each
20 independently have the above meaning for each unit.)

In addition, R_{16} in the chemical formula (16), that is, a residue having any one of a phenyl structure and a thienyl structure is selected from the group of residues represented by the chemical
25 formulae (18), (19), (20), (21), (22), (23), (24),

(25), (26), (27), and (28).

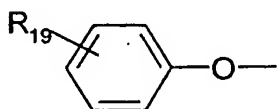
Here, the chemical formula (18) represents a group of unsubstituted or substituted phenyl groups.



(18)

- 5 (In the formula, R₁₈ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a CH=CH₂ group, COOR_{18a} (R_{18a} represents an H atom, an Na atom, or a K atom.), a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₁₈'s may be different for each unit.)
- 10

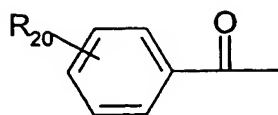
The chemical formula (19) represents a group of unsubstituted or substituted phenoxy groups.



(19)

- 15 (In the formula, R₁₉ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a SCH₃ group, a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₁₉'s may be different for each unit.)
- 20

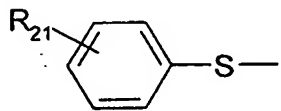
The chemical formula (20) represents a group of unsubstituted or substituted benzoyl groups.



(20)

(In the formula, R_{20} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{20} 's may be different for each unit.)

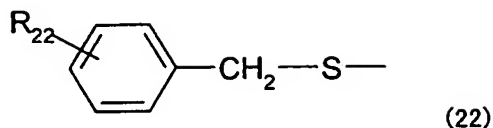
The chemical formula (21) represents a group of unsubstituted or substituted phenylsulfanyl groups.



(21)

(In the formula, R_{21} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{21a} , $\text{SO}_2\text{R}_{21b}$ (R_{21a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{21b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{21} 's may be different for each unit.)

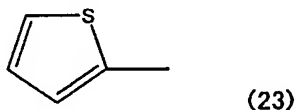
The chemical formula (22) represents a group of unsubstituted or substituted (phenylmethyl)sulfanyl groups.



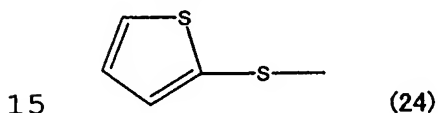
(In the formula, R_{22} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, $COOR_{22a}$, SO_2R_{22b} (R_{22a}

5 represents H, Na, K, CH_3 , or C_2H_5 , and R_{22b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(CH_3)_2-CH$ group, and a $(CH_3)_3-C$ group. When multiple units exist, R_{22} 's may be different for each unit.)

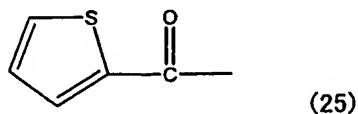
10 The chemical formula (23) represents a 2-thienyl group.



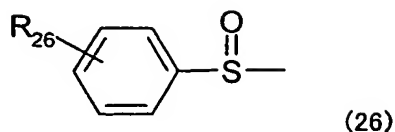
The chemical formula (24) represents a 2-thienylsulfanyl group.



15 The chemical formula (25) represents a 2-thienylcarbonyl group.



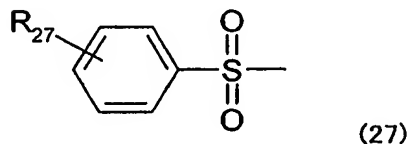
20 The chemical formula (26) represents a group of unsubstituted or substituted phenylsulfinyl groups.



(In the formula, R_{26} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{26a} , $\text{SO}_2\text{R}_{26b}$ (R_{26a}

5 represents H, Na, K, CH_3 , or C_2H_5 , and R_{26b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{26} 's may be different for each unit.)

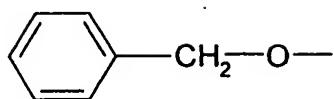
10 The chemical formula (27) represents a group of unsubstituted or substituted phenylsulfonyl groups.



(In the formula, R_{27} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{27a} , $\text{SO}_2\text{R}_{27b}$ (R_{27a}

15 represents H, Na, K, CH_3 , or C_2H_5 , and R_{27b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{27} 's
20 may be different for each unit.)

The chemical formula (28) represents a (phenylmethyl)oxy group.



(28)

On the other hand, examples of the compound represented by the chemical formula (37) to be used in the present invention include 2-acrylamide-2-methylpropanesulfonic acid, and alkali metal salts and esterified products thereof.

(Method of producing polyhydroxyalkanoate represented by chemical formula (38))

A reaction between the polyhydroxyalkanoate containing a unit represented by the chemical formula (36) and the compound represented by the chemical formula (37) in the present invention will be described in detail.

The present invention can be achieved by subjecting a α -methylene or a α -methine adjacent to a carbonyl group in a polymer main chain to a Michael addition reaction with the compound represented by the chemical formula (37). To be specific, the present invention can be achieved by allowing the polyhydroxyalkanoate containing a unit represented by the chemical formula (36) to react with a base capable of forming a α -methylene or a α -methine, which is adjacent to a carbonyl group in the polymer main chain of the polyhydroxyalkanoate containing a unit represented by the chemical formula (36), into

an anion under a Michael addition reaction condition; and allowing the resultant to react with the compound represented by the chemical formula (37). In the present invention, the amount of the compound
5 represented by the chemical formula (37) to be used is 0.001 to 100 times mole, or preferably 0.01 to 10 times mole with respect to the unit represented by the chemical formula (36).

A solvent to be used in the reaction of the
10 present invention is not particularly limited as long as it is inactive to the reaction and dissolves the starting material to some extent. Examples of such a solvent include: aliphatic hydrocarbons such as hexane, cyclohexane, heptane, ligroin, and petroleum
15 ether; aromatic hydrocarbons such as benzene, toluene, and xylene; ethers such as diethyl ether, diisopropyl ether, tetrahydrofuran, dioxane, dimethoxyethane, and diethyleneglycoldimethylether; and amides such as formamide, N,N-dimethylformamide, N,N-
20 dimethylacetamide, N-methyl-2-pyrrolidone, N-methylpyrrolidinone, and hexamethylphosphortriamide. Of those, tetrahydrofuran is preferable.

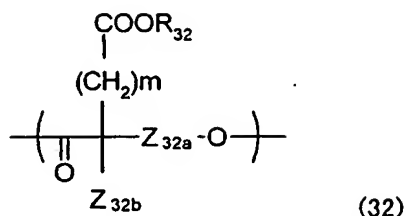
The reaction is performed in the presence of a base. Examples of a base to be used include: lithium
25 alkyls such as methyl lithium and butyl lithium; alkali metal disilazides such as lithium hexamethyl disilazide, sodium hexamethyl disilazide, and

potassium hexamethyl disilazide; and lithium amides such as lithium diisopropylamide and lithium dicyclohexylamide. Of those, lithium diisopropylamide is preferable. In addition, the
5 amount of the base to be used is 0.001 to 100 times mole, or preferably 0.01 to 10 times mole with respect to the unit represented by the chemical formula (36).

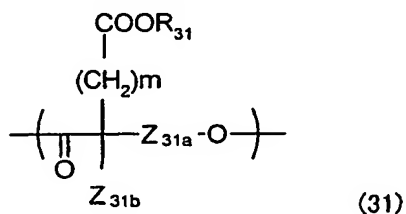
In the method of the present invention, a
10 reaction temperature is generally in the range of -78°C to 40°C , or preferably in the range of -78°C to 30°C .

In the method of the present invention, a reaction time is generally in the range of 10 minutes
15 to 24 hours. The reaction time is particularly preferably in the range of 10 minutes to 4 hours.

In addition, in the polyhydroxyalkanoate having a unit represented by the chemical formula (5) of the present invention, the polyhydroxyalkanoate having a
20 unit represented by the chemical formula (32) can be produced by hydrolyzing a side chain ester portion of a polyhydroxyalkanoate having a unit represented by the chemical formula (31) as a starting material in the presence of an acid or an alkali, or by
25 subjecting the polyhydroxyalkanoate to hydrogenolysis including catalytic reduction.



(In the formula, R_{32} represents hydrogen or a group for forming a salt. Z_{32a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear
 5 alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{32b} represents a hydrogen atom, or
 10 a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. m represents an integer selected from 0 to 8. When multiple units exist, R_{32} , Z_{32a} , Z_{32b} , and m each independently have the above meaning for each unit.)

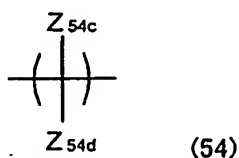


(In the formula, R_{31} represents a linear or branched alkyl or aralkyl group having 1 to 12 carbon atoms. Z_{31a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least
 20 one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a

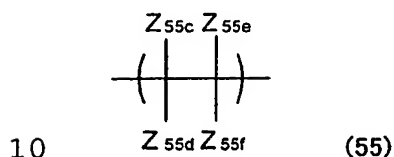
phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{31b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may
5 be substituted by an aryl group. m represents an integer selected from 0 to 8. When multiple units exist, R_{31} , Z_{31a} , Z_{31b} , and m each independently have the above meaning for each unit.)

More specifically, in each of the compounds
10 represented by the chemical formulae (31) and (32) to be used in the present invention, Z_{31a} and Z_{32a} each represent a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain is arbitrarily substituted by at least one linear or
15 branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. The linear alkylene chain structure represented by each of Z_{31a} and Z_{32a} is
20 preferably selected from the following (A) to (D).

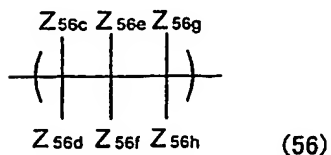
(A) When the linear alkylene chain has 1 carbon atom, in the linear alkylene chain structure represented by the chemical formula (54), one of Z_{54c} and Z_{54d} represents a linear or branched alkyl group,
25 or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



(B) When the linear alkylene chain has 2 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (55), one of Z_{55c} , Z_{55d} , Z_{55e} , and Z_{55f} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.

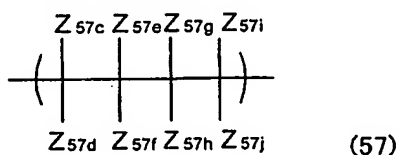


(C) When the linear alkylene chain has 3 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (56), one of Z_{56c} , Z_{56d} , Z_{56e} , Z_{56f} , Z_{56g} , and Z_{56h} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.

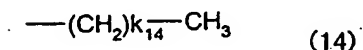


(D) When the linear alkylene chain has 4 carbon atoms, in the linear alkylene chain structure

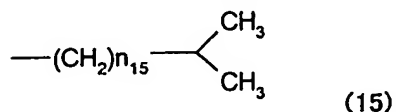
represented by the chemical formula (57), one of Z_{57c}, Z_{57d}, Z_{57e}, Z_{57f}, Z_{57g}, Z_{57h}, Z_{57i}, and Z_{57j} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



When a substituent selected from Z_{54c}, Z_{54d}, Z_{55c}, Z_{55d}, Z_{55e}, Z_{55f}, Z_{56c}, Z_{56d}, Z_{56e}, Z_{56f}, Z_{56g}, Z_{56h}, Z_{57c}, Z_{57d}, Z_{57e}, Z_{57f}, Z_{57g}, Z_{57h}, Z_{57i}, and Z_{57j} described in the chemical formulae (54), (55), (56), and (57) represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof, the substituent is more preferably selected from substituents represented by the chemical formulae (14), (15), (16), and (17).

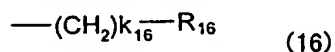


(In the formula, k₁₄ represents an integer selected from 0 to 8. When multiple units exist, k₁₄'s each independently have the above meaning for each unit.)

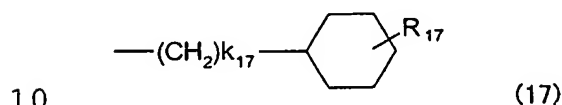


(In the formula, k₁₅ represents an integer selected

from 0 to 7. When multiple units exist, k_{15} 's each independently have the above meaning for each unit.)



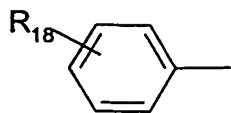
(In the formula, k_{16} represents an integer selected from 1 to 8. R_{16} represents a substituent containing a residue having any one of a phenyl structure and a thienyl structure. When multiple units exist, k_{16} and R_{16} each independently have the above meaning for each unit.)



(In the formula, R_{17} represents a substituent to a cyclohexyl group selected from an H atom, a CN group, an NO_2 group, a halogen atom, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. k_{17} represents an integer selected from 0 to 8. When multiple units exist, k_{17} and R_{17} each independently have the above meaning for each unit.)

In addition, R_{16} in the chemical formula (16), that is, a residue having any one of a phenyl structure and a thienyl structure is selected from the group of residues represented by the chemical formulae (18), (19), (20), (21), (22), (23), (24), (25), (26), (27), and (28).

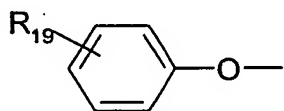
Here, the chemical formula (18) represents a group of unsubstituted or substituted phenyl groups.



(18)

(In the formula, R_{18} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $\text{CH}=\text{CH}_2$ group, COOR_{18a} (R_{18a} represents an H atom, an Na atom, or a K atom.), a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{18} 's may be different for each unit.)

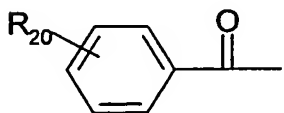
The chemical formula (19) represents a group of unsubstituted or substituted phenoxy groups.



(19)

(In the formula, R_{19} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a SCH_3 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{19} 's may be different for each unit.)

The chemical formula (20) represents a group of unsubstituted or substituted benzoyl groups.

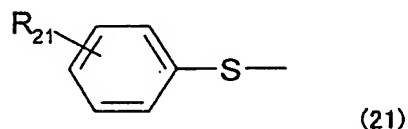


(20)

(In the formula, R_{20} represents a substituent to an

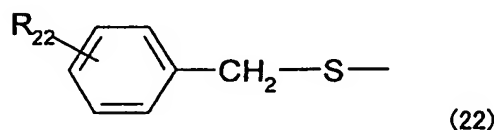
aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₂₀'s may be different for each unit.)

The chemical formula (21) represents a group of unsubstituted or substituted phenylsulfanyl groups.



(In the formula, R₂₁ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{21a}, SO₂R_{21b} (R_{21a} represents H, Na, K, CH₃, or C₂H₅, and R_{21b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₁'s may be different for each unit.)

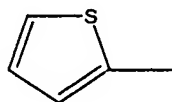
The chemical formula (22) represents a group of unsubstituted or substituted (phenylmethyl)sulfanyl groups.



(In the formula, R₂₂ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{22a}, SO₂R_{22b} (R_{22a}

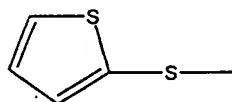
represents H, Na, K, CH₃, or C₂H₅, and R_{22b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₂'s
 5 may be different for each unit.)

The chemical formula (23) represents a 2-thienyl group.



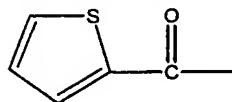
(23)

The chemical formula (24) represents a 2-thienylsulfanyl group.
 10



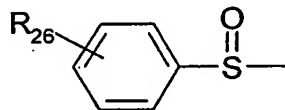
(24)

The chemical formula (25) represents a 2-thienylcarbonyl group.



(25)

The chemical formula (26) represents a group of unsubstituted or substituted phenylsulfanyl groups.
 15

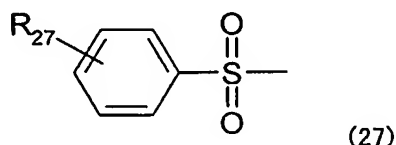


(26)

(In the formula, R₂₆ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{26a}, SO₂R_{26b} (R_{26a}
 20 represents H, Na, K, CH₃, or C₂H₅, and R_{26b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃

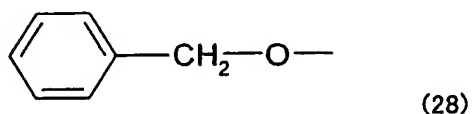
group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₆'s may be different for each unit.)

The chemical formula (27) represents a group of unsubstituted or substituted phenylsulfonyl groups.



(In the formula, R₂₇ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{27a}, SO₂R_{27b} (R_{27a} represents H, Na, K, CH₃, or C₂H₅, and R_{27b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₇'s may be different for each unit.)

The chemical formula (28) represents a (phenylmethyl)oxy group.



(Method of producing polyhydroxyalkanoate represented by chemical formula (32))

Detailed description will be given of a method of producing the polyhydroxyalkanoate having a unit represented by the chemical formula (32) by hydrolyzing a side chain ester portion of a

polyhydroxyalkanoate having a unit represented by the chemical formula (31) in the presence of an acid or an alkali, or by subjecting the polyhydroxyalkanoate to hydrogenolysis including catalytic reduction in
5 the present invention.

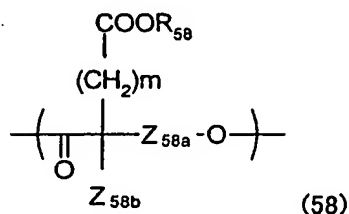
In the case where hydrolysis in the presence of an acid or an alkali is employed, the hydrolysis can be performed by using, in an aqueous solution or a hydrophilic organic solvent such as methanol, ethanol,
10 tetrahydrofuran, dioxane, dimethylformamide, or dimethyl sulfoxide as a solvent, an aqueous solution of an inorganic acid such as hydrochloric acid, sulfuric acid, nitric acid, or phosphoric acid, an organic acid such as trifluoroacetic acid,
15 trichloroacetic acid, p-toluenesulfonic acid, or methanesulfonic acid, an aqueous caustic alkali such as sodium hydroxide or potassium hydroxide, an aqueous solution of an alkali carbonate such as sodium carbonate or potassium carbonate, or an
20 alcohol solution of a metal alkoxide such as sodium methoxide or sodium ethoxide. A reaction temperature is generally in the range of 0°C to 40°C, or preferably in the range of 0°C to 30°C. A reaction time is generally in the range of 0.5 to 48 hours.
25 When hydrolysis is performed in the presence of an acid or an alkali, in each case, an ester bond of a main chain is also cleaved, and a reduction in

molecular weight is observed in some cases.

A method of obtaining a carboxylic acid by way of hydrogenolysis including catalytic reduction is performed as follows. That is, in an appropriate solvent, in the temperature range of -20°C to the boiling point of the solvent used, or preferably 0 to 50°C, in the presence of a reduction catalyst, hydrogen is allowed to act under normal or increased pressure to perform catalytic reduction. Examples of the solvent used include water, methanol, ethanol, propanol, hexafluoroisopropanol, ethyl acetate, diethyl ether, tetrahydrofuran, dioxane, benzene, toluene, dimethylformamide, pyridine, and N-methylpyrrolidone. A mixed solvent of the above solvents may also be used. A catalyst such as palladium, platinum, or rhodium which is used singly or used while being carried by a carrier, Raney nickel, or the like is used as the reduction catalyst. A reaction time is generally in the range of 0.5 to 72 hours. A thus produced reaction solution containing a polyhydroxyalkanoate having a unit represented by the chemical formula (32) is collected as a crude polymer by: removing the catalyst through filtration; and removing the solvent through distillation or the like. The resultant polyhydroxyalkanoate having a unit represented by the chemical formula (32) can be subjected to isolation

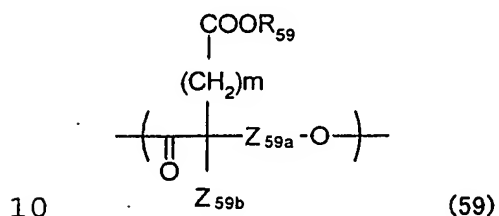
purification as required. A method for the isolation
 purification is not particularly limited, and a
 method involving reprecipitation using a solvent
 insoluble in the polyhydroxyalkanoate having a unit
 5 represented by the chemical formula (32), a method
 according to column chromatography, dialysis, or the
 like can be used. Provided, however, that even in
 the case where catalytic reduction is employed, an
 ester bond of a main chain is cleaved, and a
 10 reduction in molecular weight is observed in some
 cases.

In addition, in the polyhydroxyalkanoate having
 a unit represented by the chemical formula (5) of the
 present invention, a polyhydroxyalkanoate having a
 15 unit represented by the chemical formula (58) can be
 produced by esterifying a polyhydroxyalkanoate
 represented by the chemical formula (59) as a starting
 material by means of an esterifying agent.



20 (In the formula, R_{58} represents a linear or branched
 alkyl or aralkyl group having 1 to 12 carbon atoms.
 Z_{58a} represents a linear alkylene chain having 1 to 4
 carbon atoms. The linear alkylene chain has at least
 one linear or branched alkyl group, or at least one

alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{58b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. m represents an integer selected from 0 to 8. When multiple units exist, R_{58} , Z_{58a} , Z_{58b} , and m each independently have the above meaning for each unit.)



(In the formula, R_{59} represents hydrogen or a group for forming a salt. Z_{59a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{59b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. m represents an integer selected from 0 to 8. When multiple units exist, R_{59} , Z_{59a} , Z_{59b} , and m each independently have the above meaning for each unit.)

More specifically, in each of the compounds

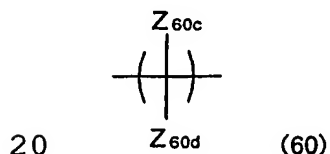
represented by the chemical formulae (58) and (59) to be used in the present invention, Z_{58a} and Z_{59a} each represent a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain is

5 arbitrarily substituted by at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. The linear alkylene

10 chain structure represented by each of Z_{58a} and Z_{59a} is preferably selected from the following (A) to (D).

(A) When the linear alkylene chain has 1 carbon atom, in the linear alkylene chain structure represented by

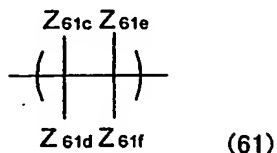
15 the chemical formula (60), one of Z_{60c} and Z_{60d} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



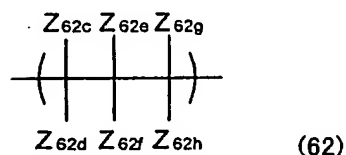
(B) When the linear alkylene chain has 2 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (61), one of Z_{61c}, Z_{61d}, Z_{61e}, and Z_{61f} represents a linear or branched alkyl group, or

25 an alkyl group containing a residue having any one of

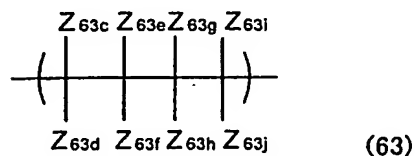
a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



- (C) When the linear alkylene chain has 3 carbon atoms,
 5 in the linear alkylene chain structure represented by
 the chemical formula (62), one of Z_{62c} , Z_{62d} , Z_{62e} , Z_{62f} ,
 Z_{62g} , and Z_{62h} represents a linear or branched alkyl
 group, or an alkyl group containing a residue having
 any one of a phenyl structure, a thienyl structure,
 10 and a cyclohexyl structure at a terminal thereof.



- (D) When the linear alkylene chain has 4 carbon atoms,
 in the linear alkylene chain structure represented by
 the chemical formula (63), one of Z_{63c} , Z_{63d} , Z_{63e} , Z_{63f} ,
 15 Z_{63g} , Z_{63h} , Z_{63i} , and Z_{63j} represents a linear or
 branched alkyl group, or an alkyl group containing a
 residue having any one of a phenyl structure, a
 thienyl structure, and a cyclohexyl structure at a
 terminal thereof.

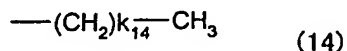


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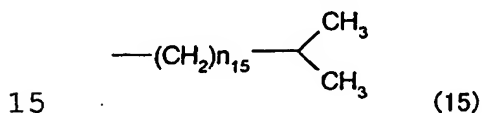
When a substituent selected from Z_{60c} , Z_{60d} , Z_{61c} ,

Z_{61d}, Z_{61e}, Z_{61f}, Z_{62c}, Z_{62d}, Z_{62e}, Z_{62f}, Z_{62g}, Z_{62h}, Z_{63c}, Z_{63d},
Z_{63e}, Z_{63f}, Z_{63g}, Z_{63h}, Z_{63i}, and Z_{63j} described in the
chemical formulae (60), (61), (62), and (63)

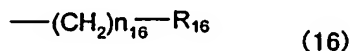
represents a linear or branched alkyl group, or an
5 alkyl group containing a residue having any one of a
phenyl structure, a thienyl structure, and a
cyclohexyl structure at a terminal thereof, the
substituent is more preferably selected from
substituents represented by the chemical formulae
10 (14), (15), (16), and (17).



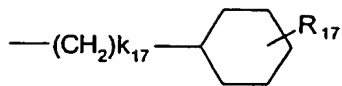
(In the formula, k_{14} represents an integer selected
from 0 to 8. When multiple units exist, k_{14} 's each
independently have the above meaning for each unit.)



(In the formula, k_{15} represents an integer selected
from 0 to 7. When multiple units exist, k_{15} 's each
independently have the above meaning for each unit.)



20 (In the formula, k_{16} represents an integer selected
from 1 to 8. R_{16} represents a substituent containing
a residue having any one of a phenyl structure and a
thienyl structure. When multiple units exist, k_{16} and
 R_{16} each independently have the above meaning for each
25 unit.)

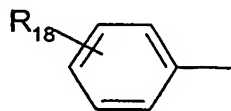


(17)

(In the formula, R_{17} represents a substituent to a cyclohexyl group selected from an H atom, a CN group, an NO_2 group, a halogen atom, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. k_{17} represents an integer selected from 0 to 8. When multiple units exist, k_{17} and R_{17} each independently have the above meaning for each unit.)

In addition, R_{16} in the chemical formula (16), that is, a residue having any one of a phenyl structure and a thienyl structure is selected from the group of residues represented by the chemical formulae (18), (19), (20), (21), (22), (23), (24), (25), (26), (27), and (28).

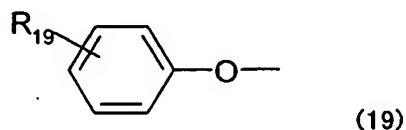
Here, the chemical formula (18) represents a group of unsubstituted or substituted phenyl groups.



(18)

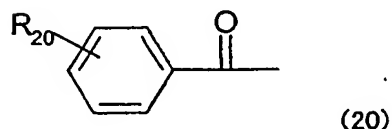
(In the formula, R_{18} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $\text{CH}=\text{CH}_2$ group, COOR_{18a} (R_{18a} represents an H atom, an Na atom, or a K atom.), a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{18} 's may be different for each unit.)

The chemical formula (19) represents a group of unsubstituted or substituted phenoxy groups.



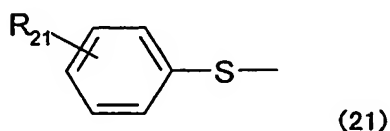
(In the formula, R_{19} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a SCH_3 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{19} 's may be different for each unit.)

10 The chemical formula (20) represents a group of unsubstituted or substituted benzoyl groups.



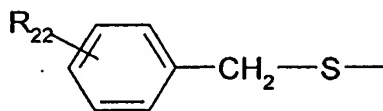
(In the formula, R_{20} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{20} 's may be different for each unit.)

20 The chemical formula (21) represents a group of unsubstituted or substituted phenylsulfanyl groups.



(In the formula, R_{21} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{21a} , $\text{SO}_2\text{R}_{21b}$ (R_{21a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{21b} represents
 5 OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{21} 's may be different for each unit.)

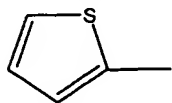
The chemical formula (22) represents a group of
 10 unsubstituted or substituted (phenylmethyl)sulfanyl groups.



(22)

(In the formula, R_{22} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{22a} , $\text{SO}_2\text{R}_{22b}$ (R_{22a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{22b} represents
 15 OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{22} 's
 20 may be different for each unit.)

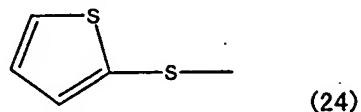
The chemical formula (23) represents a 2-thienyl group.



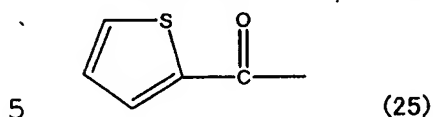
(23)

The chemical formula (24) represents a 2-

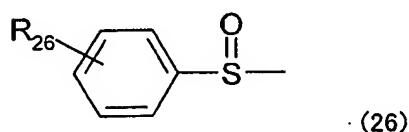
thienylsulfanyl group.



The chemical formula (25) represents a 2-thienylcarbonyl group.

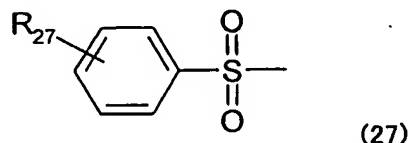


The chemical formula (26) represents a group of unsubstituted or substituted phenylsulfinyl groups.



(In the formula, R_{26} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{26a} , $\text{SO}_2\text{R}_{26b}$ (R_{26a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{26b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{26} 's may be different for each unit.)

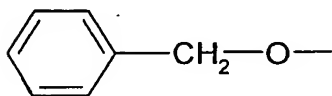
The chemical formula (27) represents a group of unsubstituted or substituted phenylsulfonyl groups.



(In the formula, R_{27} represents a substituent to an aromatic ring selected from an H atom, a halogen atom,

a CN group, an NO₂ group, COOR_{27a}, SO₂R_{27b} (R_{27a} represents H, Na, K, CH₃, or C₂H₅, and R_{27b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₇'s may be different for each unit.)

The chemical formula (28) represents a (phenylmethyl)oxy group.

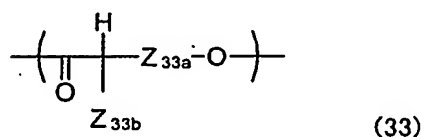


(28)

Examples of the esterifying agent to be used include diazomethane and DMF dimethylacetals. For example, the polyhydroxyalkanoate having a unit represented by the chemical formula (59) easily reacts with trimethylsilyldiazomethane, DMF dimethylacetal, DMF diethylacetal, DMF dipropylacetal, DMF diisopropylacetal, DMF-n-butylacetal, DMF-tert-butylacetal, DMF dineopentylacetal, or the like to produce a corresponding ester. Furthermore, the polyhydroxyalkanoate is allowed to react with any one of alcohols such as methanol, ethanol, propanol, isopropyl alcohol, butyl alcohol, sec-butyl alcohol, tert-butyl alcohol, pentyl alcohol, neopentyl alcohol, hexyl alcohol, heptyl alcohol, octyl alcohol, nonyl alcohol, decyl alcohol, and lauryl alcohol, or any one of saccharides for introducing a sugar structure

such as D-glucose, D-fructose, and otherwise by using an acid catalyst or a condensing agent such as DCC to produce an esterified polyhydroxyalkanoate.

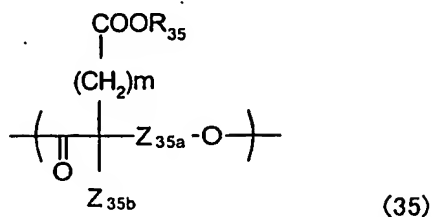
In addition, in the present invention, a
 5 polyhydroxyalkanoate containing a unit represented by the chemical formula (35) can be produced through the steps of: allowing a polyhydroxyalkanoate having a unit represented by the chemical formula (33) to react with a base; and allowing the compound obtained
 10 in the foregoing step to react with a compound represented by the chemical formula (34).



(In the formula, Z_{33a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear
 15 alkylene chain has at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{33b} represents a hydrogen atom, or
 20 a linear or branched alkyl group, aryl group, or aralkyl group which may be substituted by an aryl group. When multiple units exist, Z_{33a} and Z_{33b} each independently have the above meaning for each unit.)
 $\text{X}(\text{CH}_2)_m\text{COOR}_{34} \quad (34)$

25 (In the formula, m represents an integer selected

from 0 to 8. X represents a halogen atom. R₃₄ represents a linear or branched alkyl or aralkyl group having 1 to 12 carbon atoms.)



- 5 (In the formula, R₃₅ represents a linear or branched alkyl or aralkyl group having 1 to 12 carbon atoms. Z_{35a} represents a linear alkylene chain having 1 to 4 carbon atoms. The linear alkylene chain has at least one linear or branched alkyl group, or at least one
- 10 alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. Z_{35b} represents a hydrogen atom, or a linear or branched alkyl group, aryl group, or aralkyl group which may
- 15 be substituted by an aryl group. In addition, m represents an integer selected from 0 to 8. When multiple units exist, R₃₅, Z_{35a}, Z_{35b}, and m each independently have the above meaning for each unit.)

Alternatively, the compound (33) can be

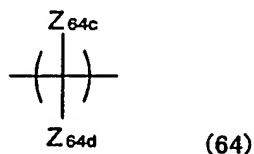
20 produced via a ring-opening polymerizable cyclic compound.

More specifically, in each of the compounds represented by the chemical formulae (33) and (35) in the present invention, Z_{33a} and Z_{35a} each represent a

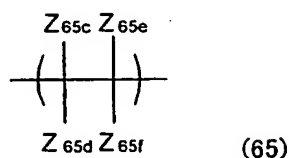
linear alkylene chain having 1 to 4 carbon atoms.

The linear alkylene chain is arbitrarily substituted by at least one linear or branched alkyl group, or at least one alkyl group containing a residue having any
 5 one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof. The linear alkylene chain structure represented by each of Z_{33a} and Z_{35a} is preferably selected from the following (A) to (D).

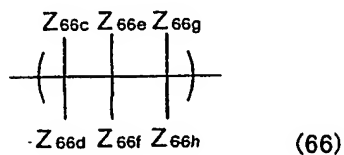
- 10 (A) When the linear alkylene chain has 1 carbon atom, in the linear alkylene chain structure represented by the chemical formula (33), one of Z_{64c} and Z_{64d} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a
 15 phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



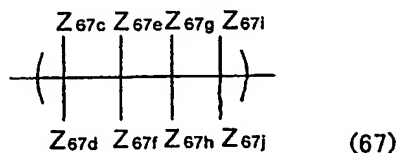
- (B) When the linear alkylene chain has 2 carbon atoms, in the linear alkylene chain structure represented by
 20 the chemical formula (65), one of Z_{65c}, Z_{65d}, Z_{65e}, and Z_{65f} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



- (C) When the linear alkylene chain has 3 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (66), one of Z_{66c}, Z_{66d}, Z_{66e}, Z_{66f}, Z_{66g}, and Z_{66h} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



- (D) When the linear alkylene chain has 4 carbon atoms, in the linear alkylene chain structure represented by the chemical formula (67), one of Z_{67c}, Z_{67d}, Z_{67e}, Z_{67f}, Z_{67g}, Z_{67h}, Z_{67i}, and Z_{67j} represents a linear or branched alkyl group, or an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof.



- When a substituent selected from Z_{64c}, Z_{64d}, Z_{65c}, Z_{65d}, Z_{65e}, Z_{65f}, Z_{66c}, Z_{66d}, Z_{66e}, Z_{66f}, Z_{66g}, Z_{66h}, Z_{67c}, Z_{67d}, Z_{67e}, Z_{67f}, Z_{67g}, Z_{67h}, Z_{67i}, and Z_{67j} described in the

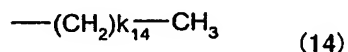
chemical formulae (64), (65), (66), and (67)

represents an alkyl group containing a residue having any one of a phenyl structure, a thienyl structure, and a cyclohexyl structure at a terminal thereof, the

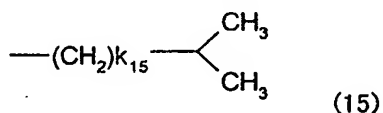
5 substituent is more preferably selected from

substituents represented by the chemical formulae

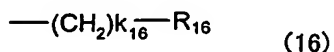
(14), (15), (16), and (17).



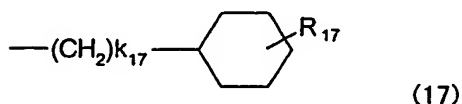
(In the formula, k_{14} represents an integer selected from 0 to 8. When multiple units exist, k_{14} 's each independently have the above meaning for each unit.)



(In the formula, k_{15} represents an integer selected from 0 to 7. When multiple units exist, k_{15} 's each independently have the above meaning for each unit.)



(In the formula, k_{16} represents an integer selected from 1 to 8. R_{16} represents a substituent containing a residue having any one of a phenyl structure and a thienyl structure. When multiple units exist, k_{16} and R_{16} each independently have the above meaning for each unit.)



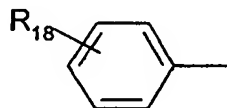
(In the formula, R_{17} represents a substituent to a cyclohexyl group selected from an H atom, a CN group,

25

an NO₂ group, a halogen atom, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a CF₃ group, a C₂F₅ group, and a C₃F₇ group. k₁₇ represents an integer selected from 0 to 8. When multiple units exist, k₁₇ and R₁₇ each independently have the above meaning for each unit.)

In addition, R₁₆ in the chemical formula (16), that is, a residue having any one of a phenyl structure and a thienyl structure is selected from the group of residues represented by the chemical formulae (18), (19), (20), (21), (22), (23), (24), (25), (26), (27), and (28).

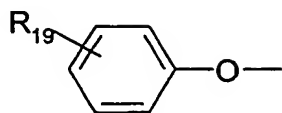
Here, the chemical formula (18) represents a group of unsubstituted or substituted phenyl groups.



(18)

(In the formula, R₁₈ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a CH=CH₂ group, COOR_{18a} (R_{18a} represents an H atom, an Na atom, or a K atom.), a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₁₈'s may be different for each unit.)

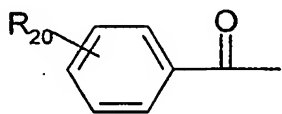
The chemical formula (19) represents a group of unsubstituted or substituted phenoxy groups.



(19)

(In the formula, R_{19} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a SCH_3 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{19} 's may be different for each unit.)

The chemical formula (20) represents a group of unsubstituted or substituted benzoyl groups.



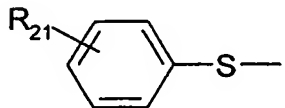
(20)

10

(In the formula, R_{20} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{20} 's may be different for each unit.)

15

The chemical formula (21) represents a group of unsubstituted or substituted phenylsulfanyl groups.



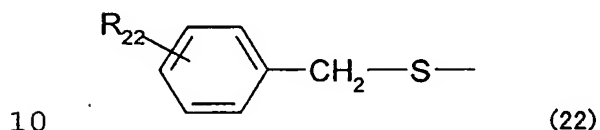
(21)

(In the formula, R_{21} represents a substituent to an aromatic ring selected from an H atom, a halogen atom,

20

a CN group, an NO₂ group, COOR_{21a}, SO₂R_{21b} (R_{21a} represents H, Na, K, CH₃, or C₂H₅, and R_{21b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₁'s may be different for each unit.)

The chemical formula (22) represents a group of unsubstituted or substituted (phenylmethyl)sulfanyl groups.

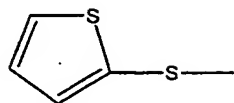


(In the formula, R₂₂ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{22a}, SO₂R_{22b} (R_{22a} represents H, Na, K, CH₃, or C₂H₅, and R_{22b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₂'s may be different for each unit.)

The chemical formula (23) represents a 2-thienyl group.

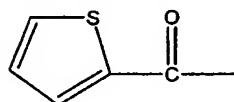


The chemical formula (24) represents a 2-thienylsulfanyl group.



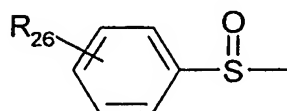
(24)

The chemical formula (25) represents a 2-thienylcarbonyl group.



(25)

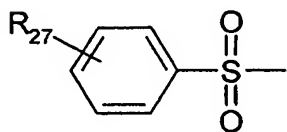
5 The chemical formula (26) represents a group of unsubstituted or substituted phenylsulfinyl groups.



(26)

(In the formula, R_{26} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{26a} , $\text{SO}_2\text{R}_{26b}$ (R_{26a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{26b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{26} 's
10 may be different for each unit.)
15

The chemical formula (27) represents a group of unsubstituted or substituted phenylsulfonyl groups.

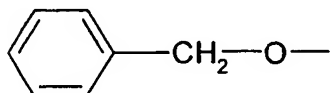


(27)

(In the formula, R_{27} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{27a} , $\text{SO}_2\text{R}_{27b}$ (R_{27a}
20

represents H, Na, K, CH₃, or C₂H₅, and R_{27b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₂₇'s
5 may be different for each unit.)

The chemical formula (28) represents a (phenylmethyl)oxy group.



(28)

Examples of the compound represented by the
10 chemical formula (34) include methyl chloroformate, ethyl chloroformate, propyl chloroformate, isopropyl chloroformate, butyl chloroformate, cyclohexyl chloroformate, benzyl chloroformate, methyl bromoformate, ethyl bromoformate, propyl bromoformate,
15 isopropyl bromoformate, butyl bromoformate, cyclohexyl bromoformate, benzyl bromoformate, methyl chloroacetate, ethyl chloroacetate, propyl chloroacetate, isopropyl chloroacetate, butyl chloroacetate, cyclohexyl chloroacetate, benzyl
20 chloroacetate, methyl bromoacetate, ethyl bromoacetate, propyl bromoacetate, isopropyl bromoacetate, butyl bromoacetate, cyclohexyl bromoacetate, benzyl bromoacetate, methyl 3-chloropropionate, ethyl 3-chloropropionate, propyl 3-chloropropionate, isopropyl 3-chloropropionate, butyl
25 chloropropionate, isopropyl 3-chloropropionate, butyl

3-chloropropionate, cyclohexyl 3-chloropropionate,
benzyl 3-chloropropionate, methyl 3-bromopropionate,
ethyl 3-bromopropionate, propyl 3-bromopropionate,
isopropyl 3-bromopropionate, butyl 3-bromopropionate,
5 cyclohexyl 3-bromopropionate, benzyl 3-
bromopropionate, methyl 4-chlorobutyrate, ethyl 4-
chlorobutyrate, propyl 4-chlorobutyrate, isopropyl 4-
chlorobutyrate, butyl 4-chlorobutyrate, cyclohexyl 4-
chlorobutyrate, benzyl 4-chlorobutyrate, methyl 4-
10 bromobutyrate, ethyl 4-bromobutyrate, propyl 4-
bromobutyrate, isopropyl 4-bromobutyrate, butyl 4-
bromobutyrate, cyclohexyl 4-bromobutyrate, benzyl 4-
bromobutyrate, methyl 5-chlorovalerate, ethyl 5-
chlorovalerate, propyl 5-chlorovalerate, isopropyl 5-
15 chlorovalerate, butyl 5-chlorovalerate, cyclohexyl 5-
chlorovalerate, benzyl 5-chlorovalerate, methyl 5-
bromovalerate, ethyl 5-bromovalerate, propyl 5-
bromovalerate, isopropyl 5-bromovalerate, butyl 5-
bromovalerate, cyclohexyl 5-bromovalerate, benzyl 5-
20 bromovalerate, methyl 6-chlorohexanoate, ethyl 6-
chlorohexanoate, propyl 6-chlorohexanoate, isopropyl
6-chlorohexanoate, butyl 6-chlorohexanoate,
cyclohexyl 6-chlorohexanoate, benzyl 6-
chlorohexanoate, methyl 6-bromohexanoate, ethyl 6-
25 bromohexanoate, propyl 6-bromohexanoate, isopropyl 6-
bromohexanoate, butyl 6-bromohexanoate, cyclohexyl 6-
bromohexanoate, benzyl 6-bromohexanoate, methyl 7-

chloroheptanoate, ethyl 7-chloroheptanoate, propyl 7-chloroheptanoate, isopropyl 7-chloroheptanoate, butyl 7-chloroheptanoate, cyclohexyl 7-chloroheptanoate, benzyl 7-chloroheptanoate, methyl 7-bromoheptanoate, ethyl 7-bromoheptanoate, propyl 7-bromoheptanoate, isopropyl 7-bromoheptanoate, butyl 7-bromoheptanoate, cyclohexyl 7-bromoheptanoate, benzyl 7-bromooctanoate, methyl 8-chlorooctanoate, ethyl 8-chlorooctanoate, propyl 8-chlorooctanoate, isopropyl 8-chlorooctanoate, butyl 8-chlorooctanoate, cyclohexyl 8-chlorooctanoate, benzyl 8-chlorooctanoate, methyl 8-bromooctanoate, ethyl 8-bromooctanoate, propyl 8-bromooctanoate, isopropyl 8-bromooctanoate, butyl 8-bromooctanoate, cyclohexyl 8-bromooctanoate, benzyl 8-bromooctanoate, methyl 9-chlorononanoate, ethyl 9-chlorononanoate, propyl 9-chlorononanoate, isopropyl 9-chlorononanoate, butyl 9-bromononanoate, cyclohexyl 9-chlorononanoate, benzyl 9-chlorononanoate, methyl 9-bromononanoate, ethyl 9-bromononanoate, propyl 9-bromononanoate, isopropyl 9-bromononanoate, butyl 9-bromononanoate, cyclohexyl 9-bromononanoate, and benzyl 9-bromononanoate.

Method of producing polyhydroxyalkanoate represented by chemical formula (35)

A reaction between the polyhydroxyalkanoate containing a unit represented by the chemical formula (33) and the compound represented by the chemical

formula (34) in the present invention will be described in detail.

The present invention can be achieved by subjecting a α -methylene or a α -methine adjacent to a carbonyl group in a polymer main chain to an addition reaction with the compound represented by the chemical formula (34). To be specific, the present invention can be achieved by: allowing the polyhydroxyalkanoate containing a unit represented by the chemical formula (33) to react with a base capable of forming a α -methylene or a α -methine, which is adjacent to a carbonyl group in the polymer main chain of the polyhydroxyalkanoate containing a unit represented by the chemical formula (33), into an anion under an addition reaction condition; and allowing the resultant to react with the compound represented by the chemical formula (34). In the present invention, the amount of the compound represented by the chemical formula (34) to be used is 0.001 to 100 times mole, or preferably 0.01 to 10 times mole with respect to the unit represented by the chemical formula (33).

~~A solvent to be used in the reaction of the~~ present invention is not particularly limited as long as it is inactive to the reaction and dissolves the starting material to some extent. Examples of such a solvent include: aliphatic hydrocarbons such as

hexane, cyclohexane, heptane, ligroin, and petroleum ether; aromatic hydrocarbons such as benzene, toluene, and xylene; ethers such as diethyl ether, diisopropyl ether, tetrahydrofuran, dioxane, dimethoxyethane, and
5 diethyleneglycoldimethylether; and amides such as formamide, N,N-dimethylformamide, N,N-dimethylacetamide, N-methyl-2-pyrrolidone, N-methylpyrrolidinone, and hexamethylphosphorotriamide. Of those, tetrahydrofuran is preferable.

10 The reaction is performed in the presence of a base. Examples of a base to be used include: lithium alkyls such as methyl lithium and butyl lithium; alkali metal disilazides such as lithium hexamethyl
15 disilazide, sodium hexamethyl disilazide, and potassium hexamethyl disilazide; and lithium amides such as lithium diisopropylamide and lithium dicyclohexylamide. Of those, lithium diisopropylamide is preferable. In addition, the
20 amount of the base to be used in the present invention is 0.001 to 100 times mole, or preferably 0.01 to 10 times mole with respect to the unit represented by the chemical formula (33).

In the method of the present invention, a reaction temperature is generally in the range of
25 -78°C to 40°C , or preferably in the range of -78°C to 30°C .

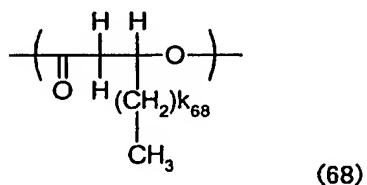
In the method of the present invention, a

reaction time is generally in the range of 10 minutes to 24 hours. The reaction time is particularly preferably in the range of 10 minutes to 4 hours.

The polyhydroxyalkanoate having a unit
5 represented by the chemical formula (33) included in the chemical formula (5) can be produced according to the above production method.

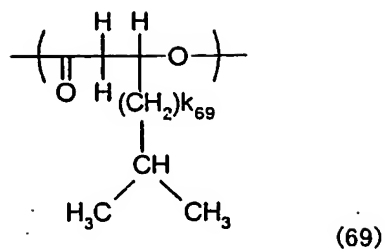
In addition, a polymer produced by means of a conventionally known method can be arbitrarily used
10 as the polyhydroxyalkanoate containing a unit represented by one of the chemical formulae (33) and (36) to be used in the present invention. Examples of a polyhydroxyalkanoate represented by the chemical formula (68) included in the chemical formulae (33)
15 and (35) include organism-produced polyesters typified by poly-3-hydroxybutyrate (k_{68} in the chemical formula (68) represents 0), poly-3-hydroxyvalerate (k_{68} in the chemical formula (68) represents 1), and the like. For example, JP-B H07-
20 14352 and JP-B H08-19227 each disclose a method of producing a copolymer of 3-hydroxybutyrate and 3-hydroxyvalerate. In addition, JP-A H05-93049 and JP-A H07-265065 each disclose a method of producing a copolymer of 3-hydroxybutyrate and 3-hydroxyhexanoate
25 (k_{68} represents 2). In addition, JP 2642937 B discloses a method of producing a copolymer containing a 3-hydroxyalkanoate having 6 to 12 carbon

atoms (that is, from 3-hydroxyhexanoate to 3-hydroxyundecanoate). JP-A 2002-306190 discloses a method of producing a homopolymer of poly-3-hydroxybutyrate. A polyhydroxyalkanoate can be produced in the present invention by means of a similar method. In addition, a polyhydroxyalkanoate containing a unit represented by the chemical formula (69) included in the chemical formulae (33) and (35) can be produced by means of a method disclosed in International Journal of Biological Macromolecules (1990) 92. In addition, a method of producing a polyhydroxyalkanoate containing a unit represented by the chemical formula (70) or (71) included in the chemical formulae (33) and (35) is disclosed in JP-A 2001-288256 and JP-A 2003-319792. A polyhydroxyalkanoate can be produced in the present invention by means of a similar method.

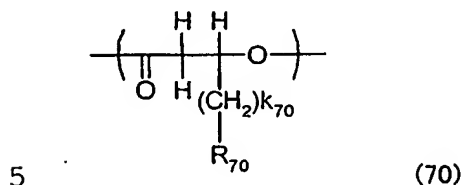


(k_{68} represents an integer, selected from 0 to 8.

When multiple units exist, k_{68} 's each independently have the above meaning for each unit.)

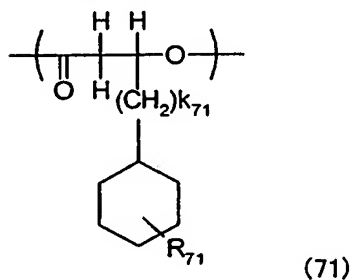


(k_{69} represents an integer selected from 0 to 7. When multiple units exist, k_{69} 's each independently have the above meaning for each unit.)



(k_{70} represents an integer selected from 1 to 8. R_{70} represents a substituent containing a residue having any one of a phenyl structure and a thienyl structure. When multiple units exist, k_{70} and R_{70} each

10 independently have the above meaning for each unit.)



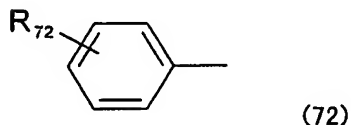
(In the formula, R_{71} represents a substituent to a cyclohexyl group selected from an H atom, a CN group, an NO_2 group, a halogen atom, a CH_3 group, a C_2H_5 group, a C_3H_7 group, a CF_3 group, a C_2F_5 group, and a C_3F_7 group. k_{71} represents an integer selected from 0

15

to 8. When multiple units exist, k_{71} and R_{71} each independently have the above meaning for each unit.)

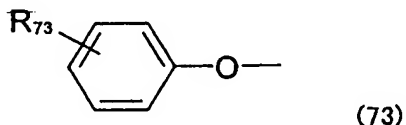
In addition, R_{70} in the chemical formula (70), that is, a residue having any one of a phenyl
5 structure and a thienyl structure is selected from the group of residues represented by the chemical formulae (72), (73), (74), (75), (76), (77), (78), (79), (80), (81), and (82).

Here, the chemical formula (72) represents a
10 group of unsubstituted or substituted phenyl groups.



(In the formula, R_{72} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, a CH_3 group, a C_2H_5 group, a
15 C_3H_7 group, a $\text{CH}=\text{CH}_2$ group, COOR_{72a} (R_{72a} represents an H atom, an Na atom, or a K atom.), a CF_3 group, a C_2F_5 group, and a C_3F_7 group. When multiple units exist, R_{72} 's may be different for each unit.)

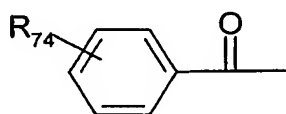
The chemical formula (73) represents a group of
20 unsubstituted or substituted phenoxy groups.



(In the formula, R_{73} represents a substituent to an aromatic ring selected from an H atom, a halogen atom,

a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a SCH₃ group, a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₇₃'s may be different for each unit.)

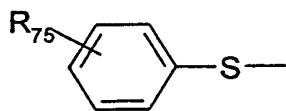
- 5 The chemical formula (74) represents a group of unsubstituted or substituted benzoyl groups.



(74)

- (In the formula, R₇₄ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, a CH₃ group, a C₂H₅ group, a C₃H₇ group, a CF₃ group, a C₂F₅ group, and a C₃F₇ group. When multiple units exist, R₇₄'s may be different for each unit.)

- 15 The chemical formula (75) represents a group of unsubstituted or substituted phenylsulfanyl groups.

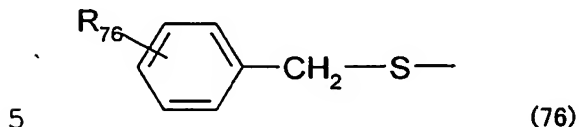


(75)

- (In the formula, R₇₅ represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO₂ group, COOR_{75a}, SO₂R_{75b} (R_{75a} represents H, Na, K, CH₃, or C₂H₅, and R_{75b} represents OH, ONa, OK, a halogen atom, OCH₃, or OC₂H₅.), a CH₃ group, a C₂H₅ group, a C₃H₇ group, a (CH₃)₂-CH group, and a (CH₃)₃-C group. When multiple units exist, R₇₅'s

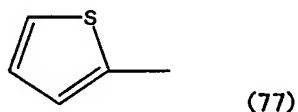
may be different for each unit.)

The chemical formula (76) represents a group of unsubstituted or substituted (phenylmethyl)sulfanyl groups.

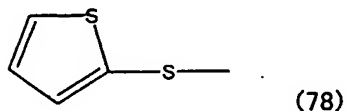


(In the formula, R_{76} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{76a} , $\text{SO}_2\text{R}_{76b}$ (R_{76a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{76b} represents
10 OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{76} 's may be different for each unit.)

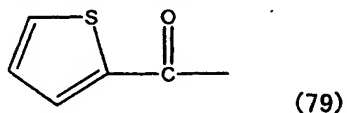
The chemical formula (77) represents a 2-
15 thienyl group.



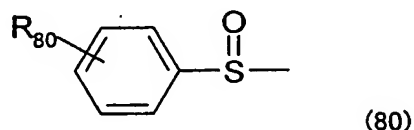
The chemical formula (78) represents a 2-thienylsulfanyl group.



20 The chemical formula (79) represents a 2-thienylcarbonyl group.

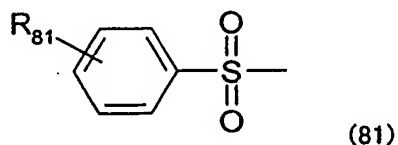


The chemical formula (80) represents a group of unsubstituted or substituted phenylsulfinyl groups.



(In the formula, R_{80} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{80a} , SO_2R_{80b} (R_{80a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{80b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{80} 's may be different for each unit.)

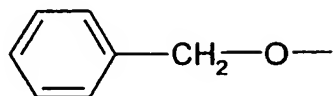
The chemical formula (81) represents a group of unsubstituted or substituted phenylsulfonyl groups.



(In the formula, R_{81} represents a substituent to an aromatic ring selected from an H atom, a halogen atom, a CN group, an NO_2 group, COOR_{81a} , SO_2R_{81b} (R_{81a} represents H, Na, K, CH_3 , or C_2H_5 , and R_{81b} represents OH, ONa, OK, a halogen atom, OCH_3 , or OC_2H_5 .), a CH_3 group, a C_2H_5 group, a C_3H_7 group, a $(\text{CH}_3)_2\text{-CH}$ group, and a $(\text{CH}_3)_3\text{-C}$ group. When multiple units exist, R_{81} 's may be different for each unit.)

The chemical formula (82) represents a group of

unsubstituted or substituted (phenylmethyl)oxy groups.



(82)

The novel polyhydroxyalkanoate and the method of producing the same shown in the present invention are provided by using a polyhydroxyalkanoate containing a unit represented by the chemical formula (33) or (35) including the chemical formulae (68), (69), (70), and (71) as a starting material. However, the present invention is not limited to the method described above.

The molecular weight of the polyhydroxyalkanoate of the present invention can be measured as a relative molecular weight or an absolute molecular weight. The molecular weight can be simply measured by means of, for example, gel permeation chromatography (GPC). A specific measurement method by means of GPC is as follows. The polyhydroxyalkanoate is dissolved in advance into a solvent into which the polyhydroxyalkanoate is soluble, and the molecular weight is measured in a mobile phase of the same solvent. A differential refractometer (RI) or an ultraviolet (UV) detector can be used as a detector depending on the polyhydroxyalkanoate to be measured. The molecular weight is determined as a result of relative

comparison with a standard sample (such as polystyrene or polymethyl methacrylate). The solvent can be selected from solvents into each of which a polymer is soluble such as dimethylformamide (DMF),
5 dimethyl sulfoxide (DMSO), chloroform, tetrahydrofuran (THF), toluene, and hexafluoroisopropanol (HFIP). In the case of a polar solvent, the molecular weight can be measured through addition of a salt.

10 The number average molecular weight of a polyhydroxyalkanoate to be produced by the present invention can vary widely by changing conditions including a reaction time, a reaction temperature, and a reaction time. The optimum number average
15 molecular weight of the polyhydroxyalkanoate, which varies depending on a target function, is in the range of 1,000 to 1,000,000 when one attempts to use the polyhydroxyalkanoate for a medical soft member or the like. In addition, a polyhydroxyalkanoate having
20 a ratio (M_w/M_n) between a weight average molecular weight (M_w) and the number average molecular weight (M_n) in the range of 1 to 10 is preferable.

A reaction solvent, a reaction temperature, a reaction time, a purification method, and the like in
25 a chemical reaction of the present invention are not limited to those described above.

[EXAMPLES]

Hereinafter, the present invention will be described in more detail by way of examples. However, the present invention is not limited to these
5 examples.

In each of Examples 1 to 4, a microorganism is used to produce a polyhydroxyalkanoate. The microorganisms used in those examples are a *Ralstonia eutropha* TB64 strain (disclosed in JP-A 2000-166587)
10 and a *Pseudomonas cichorii* YN2 strain (FERM BP-7375, disclosed in JP-A 2001-288256). Those 2 microorganisms are deposited in the National Institute of Advanced Industrial Science and Technology, International Patent Organism Depository.

15 The mineral salt medium (M9 medium) used in each of Examples 1 to 4 has the following composition.

M9 medium composition (in 1 L)

	Na_2HPO_4	6.2 g
	KH_2PO_4	3.0 g
20	NaCl	0.5 g
	NH_4Cl	1.0 g
	Water	Balance
	(pH 7.0)	

For better proliferation of a microorganism and
25 better production of a polyhydroxyalkanoate at the time of culture, the above mineral salt is added with about 0.3% (volume/volume) of a trace component

solution shown below.

(Trace component solution composition: unit g/L)

Nitrilotriacetic acid: 1.5; MgSO₄: 3.0; MnSO₄: 0.5;

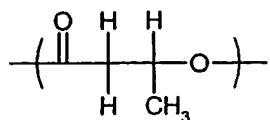
NaCl: 1.0; FeSO₄: 0.1; CaCl₂: 0.1; CoCl₂: 0.1; ZnSO₄:

5 0.1; CuSO₄: 0.1; AlK(SO₄)₂: 0.1; H₃BO₃: 0.1; Na₂MoO₄:

0.1; NiCl₂: 0.1

[Example 1]

(Synthesis of poly-3-hydroxybutyric acid represented by chemical formula (101))



B

(101)

10

Poly-3-hydroxybutyric acid represented by the chemical formula (101) was synthesized by means of the method disclosed in Example 1 of JP-A 2002-306190.

A colony of a TB 64 strain on an M9 agar medium
 15 containing 0.1% of sodium malate was inoculated in 50 ml of an M9 medium containing 0.5% of sodium malate in a 500-mL shaking flask, and the whole was shake cultured at 30°C. 24 hours after that, 5 ml of the culture solution were added to 1 L of a production
 20 medium prepared by incorporating 0.5% of sodium malate into an M9 medium with the concentration of only NH₄Cl as a nitrogen source reduced to 1/10, and the whole was shaken in the same manner to accumulate PHB in the cells. 48 hours after that, the cells

were recovered by centrifugal separation, washed with methanol, and then freeze-dried. After the dried cells had been weighed, chloroform was added, and the whole was stirred at 60°C for 24 hours to extract a
5 polymer.

After filtrating the extracted chloroform solution through a filter, it was concentrated by means of an evaporator. After that, a portion precipitated and solidified with cold methanol was collected and dried
10 under reduced pressure to prepare 1.83 g of a polymer per L of the production medium. NMR analysis was performed under the following conditions to determine the structure of the resultant polymer.

<Measuring equipment> FT-NMR: Bruker DPX 400

15 Resonance frequency: ^1H = 400 MHz

<Measurement conditions> Measured nuclear species: ^1H

Solvent used: CDCl_3

Measurement temperature: room temperature

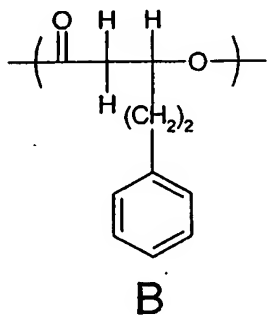
The analysis confirmed that the resultant
20 polymer was a polyhydroxyalkanoate containing a unit of 3-hydroxybutyric acid represented by the chemical formula (1). The resultant polyhydroxyalkanoate was evaluated for average molecular weight by means of gel permeation chromatography (GPC; HLC-8220
25 manufactured by Tosoh Corporation, column; TSK-GEL Super HM-H manufactured by Tosoh Corporation, solvent; chloroform, polystyrene conversion). As a

result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 549,500 and a weight average molecular weight M_w of 1,263,900.

5 45.6 g of the polyhydroxyalkanoate to be used in each of Examples 5 to 8 was prepared from 50 L of the production medium by means of the above method.

[Example 2]

(Synthesis of poly-3-hydroxy-5-phenylvaleric acid
10 represented by chemical formula (102))



Poly-3-hydroxy-5-phenylvaleric acid represented by the chemical formula (102) was synthesized by means of the method disclosed in Example 1 of JP-A
15 2003-319792. 200 mL of an M9 medium containing 0.5% (weight/volume (w/v)) of polypeptone (Wako Pure Chemical Industries, Ltd.) and 0.1% (weight/volume (w/v)) of 5-phenylvaleric acid were prepared as a production medium. 1 mL of a culture solution
20 prepared in advance by shake culturing a *Pseudomonas cichorii* YN2 strain in an M9 medium containing 0.5% of polypeptone at 30°C for 8 hours was added to the

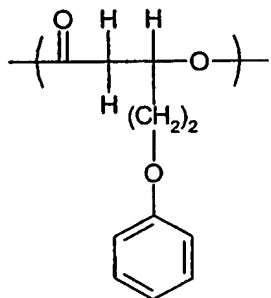
production medium, and the whole was cultured in a 500-mL shaking flask at 30°C for 24 hours. After the culture, the cells were recovered by centrifugal separation, washed with methanol, and then freeze-dried. After the dried cells had been weighed, chloroform was added, and the whole was stirred at 50°C for 24 hours to extract a polymer. After filtrating the extracted chloroform solution through a filter, it was concentrated by means of an evaporator. After that, a portion precipitated and solidified with cold methanol was collected and dried under reduced pressure to prepare 0.60 g of a polymer per L of the production medium. NMR analysis was performed under the same conditions as those of Example 1 to determine the structure of the resultant polymer. The analysis confirmed that the resultant polymer was substantially a homopolymer of a unit of poly-3-hydroxy-5-phenylvaleric acid represented by the chemical formula (102) as a monomer unit. The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 91,000 and a weight average molecular weight M_w of 172,900.

60.1 g of the polyhydroxyalkanoate to be used in each of Examples 9 to 12 was prepared from 100 L

of the production medium by means of the above method.

[Example 3]

(Synthesis of poly-3-hydroxy-5-phenoxyvaleric acid represented by chemical formula (103))



B

(103)

5

Poly-3-hydroxy-5-phenylvaleric acid represented by the chemical formula (103) was synthesized by means of the method disclosed in Example 4 of JP-A 2003-319792.

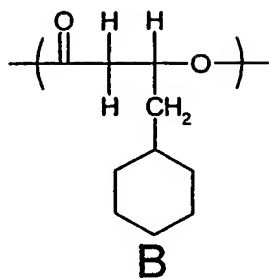
10 200 mL of an M9 medium containing 0.5% (weight/volume (w/v)) of polypeptone (Wako Pure Chemical Industries, Ltd.) and 0.1% (weight/volume (w/v)) of 5-phenoxyvaleric acid was prepared as a production medium. 1 mL of a culture solution

15 prepared in advance by shake culturing a *Pseudomonas cichorii* YN2 strain in an M9 medium containing 0.5% of polypeptone at 30°C for 8 hours was added to the production medium, and the whole was cultured in a 500-mL shaking flask at 30°C for 45 hours. After the

20 culture, the cells were recovered by centrifugal separation, washed with methanol, and then freeze-

dried. After the dried cells had been weighed, chloroform was added, and the whole was stirred at 50°C for 24 hours to extract a polymer. After filtrating the extracted chloroform solution through
5 a filter, it was concentrated by means of an evaporator. After that, a portion precipitated and solidified with cold methanol was collected and dried under reduced pressure to prepare 0.36 g of a polymer per L of the production medium. NMR analysis was
10 performed under the same conditions as those of Example 1 to determine the structure of the resultant polymer. The analysis confirmed that the resultant polymer was substantially a homopolymer of a unit of poly-3-hydroxy-5-phenoxyvaleric acid represented by
15 the chemical formula (103) as a monomer unit. The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a
20 number average molecular weight Mn of 201,000 and a weight average molecular weight Mw of 422,100.

44.8 g of the polyhydroxyalkanoate to be used in each of Examples 13 to 16 was prepared from 125 L of the production medium by means of the above method.
25 [Example 4]
(Synthesis of poly-3-hydroxy-4-cyclohexylbutyric acid represented by chemical formula (104))



(104)

Poly-3-hydroxy-4-cyclohexylbutyric acid represented by the chemical formula (104) was synthesized by means of the method disclosed in
5 Example 9 of JP-A 2003-319792.

200 mL of an M9 medium containing 0.5% (weight/volume (w/v)) of polypeptone (Wako Pure Chemical Industries, Ltd.) and 0.1% (weight/volume (w/v)) of 4-cyclohexylbutyric acid was prepared as a
10 production medium. 1 mL of a culture solution prepared in advance by shake culturing a *Pseudomonas cichorii* YN2 strain in an M9 medium containing 0.5% of polypeptone at 30°C for 8 hours was added to the production medium, and the whole was cultured in a
15 500-mL shaking flask at 30°C for 48 hours. After the culture, the cells were recovered by centrifugal separation, washed with methanol, and then freeze-dried. After the dried cells had been weighed, chloroform was added, and the whole was stirred at
20 50°C for 24 hours to extract a polymer. After filtrating the extracted chloroform solution through a filter, it was concentrated by means of an evaporator. After that, a portion precipitated and

solidified with cold methanol was collected and dried under reduced pressure to prepare 0.48 g of a polymer per L of the production medium. NMR analysis was performed under the same conditions as those of

5 Example 1 to determine the structure of the resultant polymer. The analysis confirmed that the resultant polymer was substantially a homopolymer of a unit of poly-3-hydroxy-4-cyclohexylbutyric acid represented by the chemical formula (104) as a monomer unit. The

10 average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 70,500 and a

15 weight average molecular weight Mw of 155,100.

47.9 g of the polyhydroxyalkanoate to be used in each of Examples 17 and 18 was prepared from 100 L of the production medium by means of the above method.

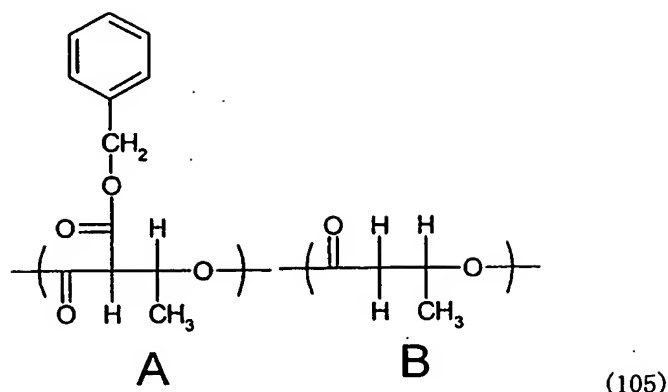
[Example 5]

20 10.00 g of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (101) synthesized in Example 1 was placed in a round-bottomed flask, and 500 ml of THF was added to dissolve this. The flask was placed under a nitrogen

25 atmosphere, and the solution was stirred at -78°C. Next, 58.08 ml (116.2 mmol) of a solution of 2 M of lithium diisopropylamide in THF was gradually added

to the flask, and the whole was stirred at -78°C for 30 minutes. Next, 19.82 g (232.3 mmol) of benzyl chloroformate was added to the flask, and the whole was stirred at room temperature for 30 minutes.

- 5 After the completion of the reaction, the reaction solution was poured into 1,000 ml of an aqueous solution of ammonium chloride, and 500 ml of dichloromethane was added to extract the organic layer. The extracted organic layer was washed with
10 250 ml of water 3 times. After the organic layer had been collected, the solvent was distilled off to collect a crude polymer. Next, the polymer was dissolved into 60 ml of THF, and reprecipitated in methanol in an amount 50 times that of THF necessary
15 for the dissolution. The precipitate was collected and dried under reduced pressure to prepare 8.44 g of a polymer. NMR analysis was performed under the same conditions as those of Example 1 to determine the structure of the resultant polymer. The analysis
20 confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (105) as a monomer unit. The analysis also confirmed that an A unit accounted for 10 mol% of the monomer unit and a B unit accounted
25 for 90 mol% thereof.

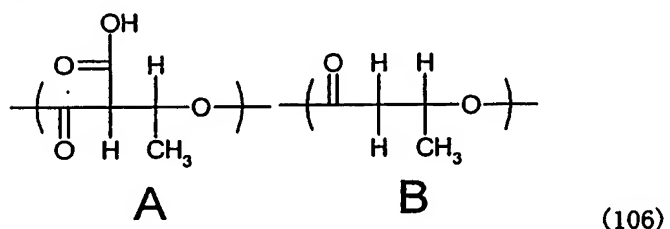


The resultant polyhydroxyalkanoate was evaluated for average molecular weight by means of gel permeation chromatography (GPC; HLC-8220 manufactured by Tosoh Corporation, column; TSK-GEL Super HM-H manufactured by Tosoh Corporation, solvent; chloroform, polystyrene conversion). As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 325,400 and a weight average molecular weight M_w of 764,700.

5.00 g of the polyhydroxyalkanoate copolymer represented by the chemical formula (105) synthesized here was dissolved into 500 ml of a mixed solvent of dioxane-ethanol (75 : 25), and 1.10 g of a 5% palladium/carbon catalyst was added to the solution. The inside of the reaction system was filled with hydrogen, and the whole was stirred at room temperature for 1 day. After the completion of the reaction, in order to remove the catalyst, the resultant was filtered through a 0.25- μ m membrane

filter to collect a reaction solution. After the solution had been concentrated, the concentrate was dissolved into chloroform, and reprecipitated in methanol in an amount 10 times that of chloroform.

- 5 The resultant polymer was collected and dried under reduced pressure to prepare 3.59 g of a polymer. NMR analysis was performed under the same conditions as those of Example 6 to determine the structure of the resultant polymer. The analysis confirmed that the
- 10 polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (106) as a monomer unit. The analysis also confirmed that a C unit accounted for 10 mol% of the monomer unit and a D unit accounted
- 15 for 90 mol% thereof.



- The resultant polyhydroxyalkanoate was evaluated for average molecular weight by means of gel permeation chromatography (GPC; HLC-8220
- 20 manufactured by Tosoh Corporation, column; TSK-GEL Super HM-H manufactured by Tosoh Corporation, solvent; chloroform, polystyrene conversion). As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of

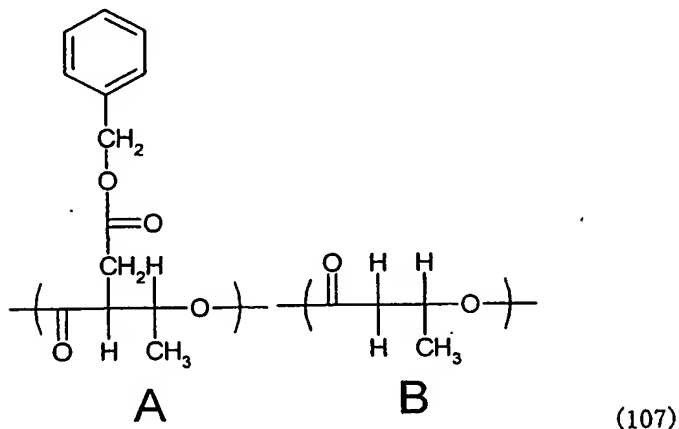
298,000 and a weight average molecular weight Mw of 715,200.

Furthermore, 30 mg of the polyhydroxyalkanoate synthesized here was placed in a 100-ml round-bottomed flask, and 2.1 ml of chloroform and 0.7 ml of methanol were added to dissolve this. 0.5 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution was added to the solution, and the whole was stirred at room temperature for 1 hour. After the completion of the reaction, the solvent was distilled off to collect a polymer. The polymer was washed with 50 ml of methanol to collect a polymer. The polymer was dried under reduced pressure to prepare 29 mg of a polyhydroxyalkanoate. The resultant polyhydroxyalkanoate was subjected to NMR analysis in the same manner as in Example 1. The analysis confirmed that a carboxyl group of the C unit was transformed into methyl carboxylate, and that the resultant polymer can be esterified again:

[Example 6]

9.40 g of a polymer was prepared in the same manner as in Example 5 except that 26.61 g (232.3 mmol) of benzyl bromoacetate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a

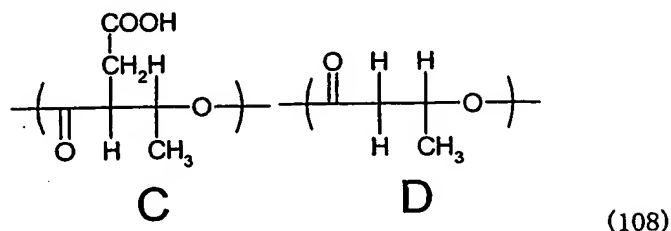
unit represented by the following chemical formula (107). The analysis also confirmed that an A unit accounted for 11 mol% of the monomer unit and a B unit accounted for 89 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 300,300 and a weight average molecular weight M_w of 723,700.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.66 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (108) as a monomer unit. The analysis also confirmed that a C unit accounted

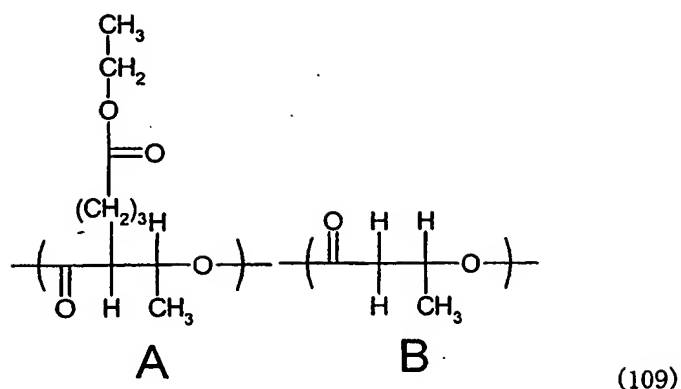
for 11 mol% of the monomer unit and a D unit accounted for 89 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 286,000 and a weight average molecular weight M_w of 700,700.

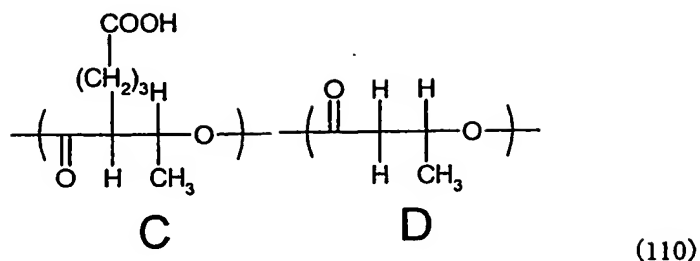
10 [Example 7]

8.49 g of a polymer was prepared in the same manner as in Example 5 except that 22.66 g (232.3 mmol) of ethyl 4-bromobutylate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (109). The analysis also confirmed that an A unit accounted for 10 mol% of the monomer unit and a B unit accounted for 90 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 300,300 and a weight average molecular weight Mw of 723,700.

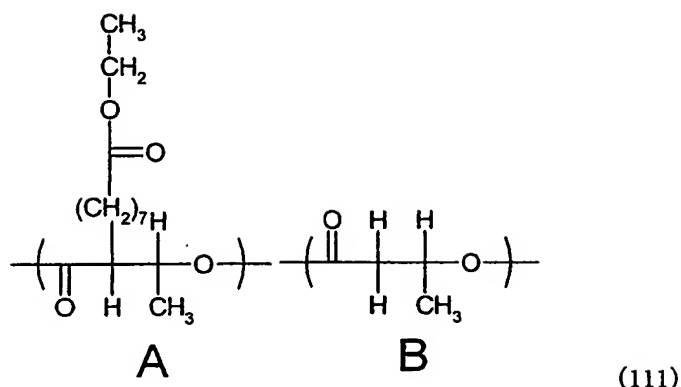
The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.93 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (110) as a monomer unit. The analysis also confirmed that a C unit accounted for 10 mol% of the monomer unit and a D unit accounted for 90 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 286,000 and a weight average molecular weight Mw of 700,700.

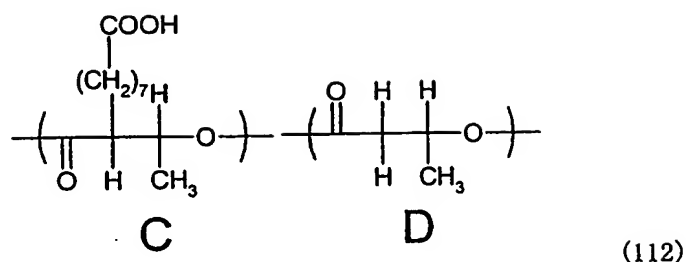
[Example 8]

8.83 g of a polymer was prepared in the same manner as in Example 5 except that 29.17 g (232.3 mmol) of ethyl 8-bromooctanoate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (111). The analysis also confirmed that an A unit accounted for 9 mol% of the monomer unit and a B unit accounted for 91 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 321,000 and a weight average molecular weight Mw of 776,800.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.85 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (112) as a monomer unit. The analysis also confirmed that a C unit accounted for 9 mol% of the monomer unit and a D unit accounted for 91 mol% thereof.

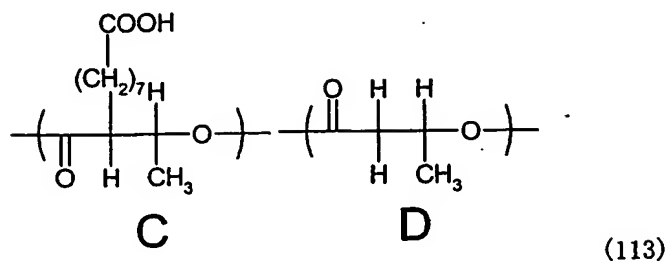


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 298,100 and a weight average molecular weight Mw of 715,400.

[Example 9]

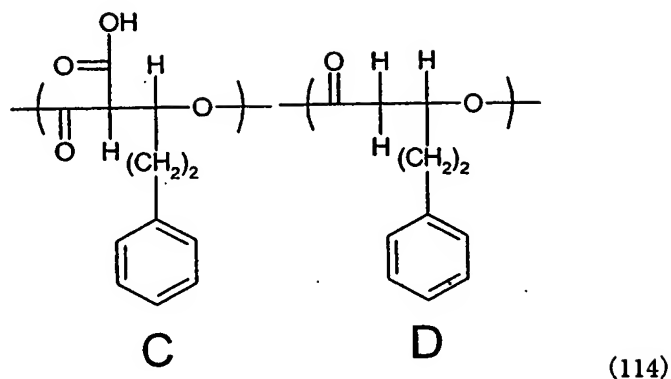
8.51 g of a polymer was prepared in the same manner as in Example 5 except that 10.00 g of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (102) synthesized in Example 2 instead of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (101), 28.38 ml (56.8 mmol) of a solution of 2 M of lithium diisopropylamide in THF, and 9.68 g (113.5 mmol) of benzyl chloroformate were used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (113). The analysis also confirmed that an A unit accounted for 12 mol% of the monomer

unit and a B unit accounted for 88 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 72,500 and a weight average molecular weight Mw of 141,400.

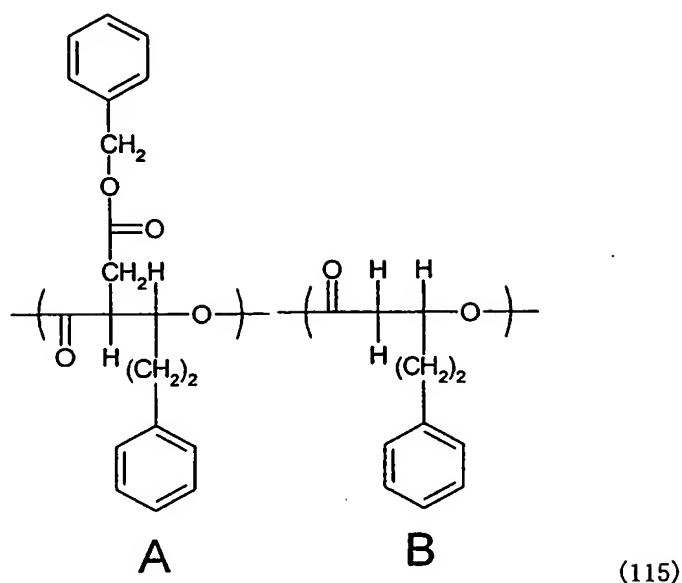
The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.72 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (114) as a monomer unit. The analysis also confirmed that a C unit accounted for 12 mol% of the monomer unit and a D unit accounted for 88-mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 69,500 and a weight average molecular weight M_w of 139,700.

[Example 10]

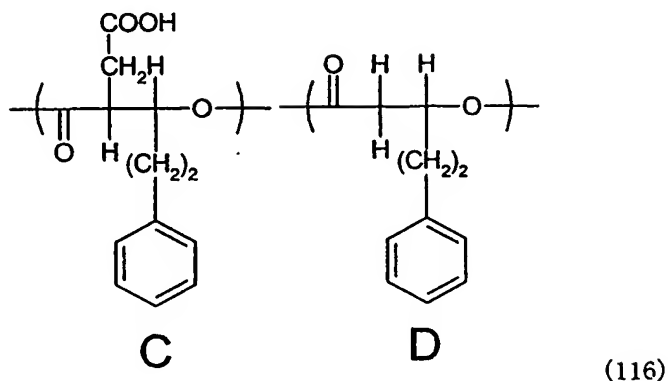
8.37 g of a polymer was prepared in the same manner as in Example 9 except that 13.00 g (113.5 mmol) of benzyl bromoacetate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (115). The analysis also confirmed that an A unit accounted for 12 mol% of the monomer unit and a B unit accounted for 88 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 71,000 and a weight average molecular weight M_w of 131,400.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.87 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (116) as a monomer unit. The analysis also confirmed that a C unit accounted for 12 mol% of the monomer unit and a D unit

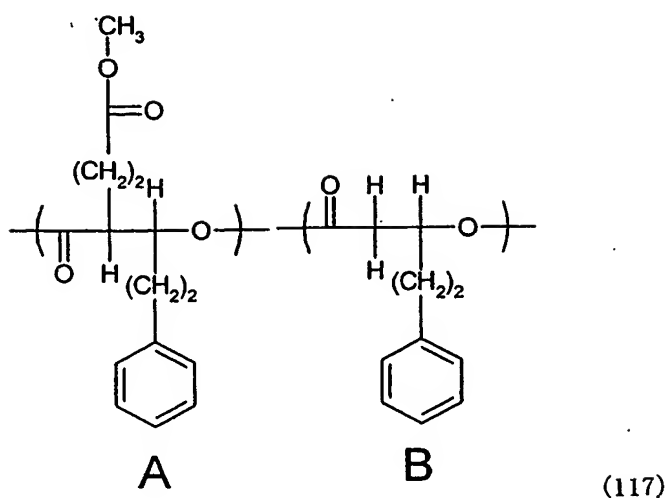
accounted for 88 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 68,000 and a weight average molecular weight Mw of 132,600.

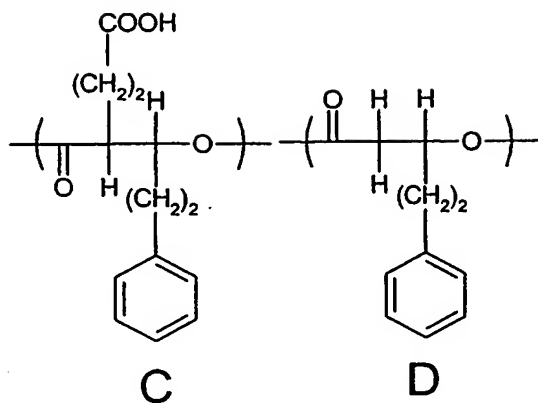
[Example 11]

7.80 g of a polymer was prepared in the same manner as in Example 9 except that 9.48 g (113.5 mmol) of methyl 3-bromopropionate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (117). The analysis also confirmed that an A unit accounted for 11 mol% of the monomer unit and a B unit accounted for 89 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 68,500 and a weight average molecular weight M_w of 130,800.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 4.01 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (118) as a monomer unit. The analysis also confirmed that a C unit accounted for 11 mol% of the monomer unit and a D unit accounted for 89 mol% thereof.

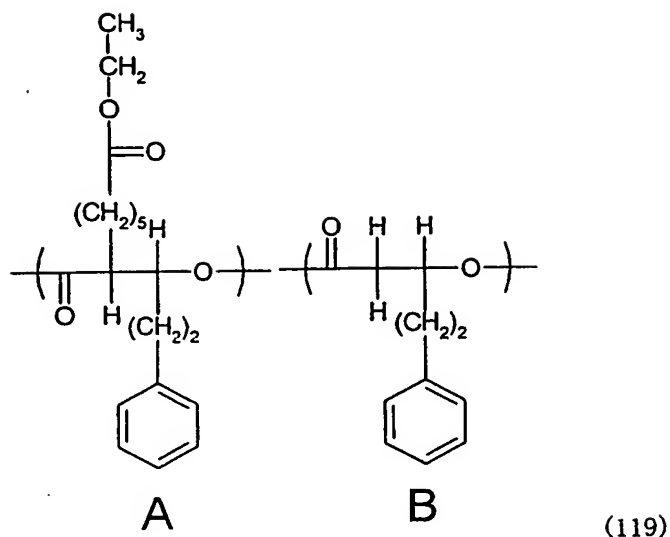


(118)

The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 67,000 and a weight average molecular weight Mw of 127,300.

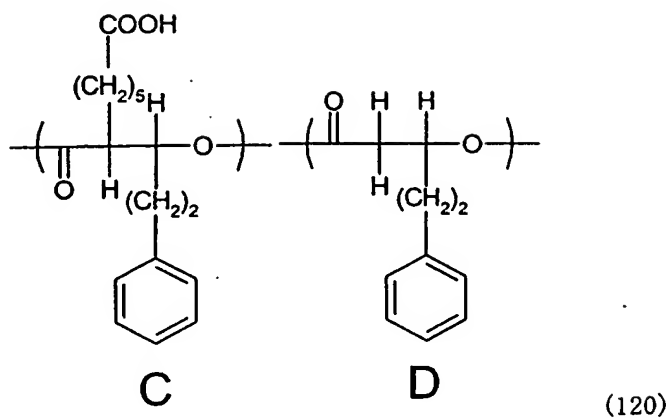
[Example 12]

7.87 g of a polymer was prepared in the same manner as in Example 9 except that 12.86 g (113.5 mmol) of ethyl 6-bromohexanoate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (119). The analysis also confirmed that an A unit accounted for 8 mol% of the monomer unit and a B unit accounted for 92 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 71,000 and a weight average molecular weight M_w of 134,900.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.95 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (120) as a monomer unit. The analysis also confirmed that a C unit accounted for 8 mol% of the monomer unit and a D unit accounted for 92 mol% thereof.

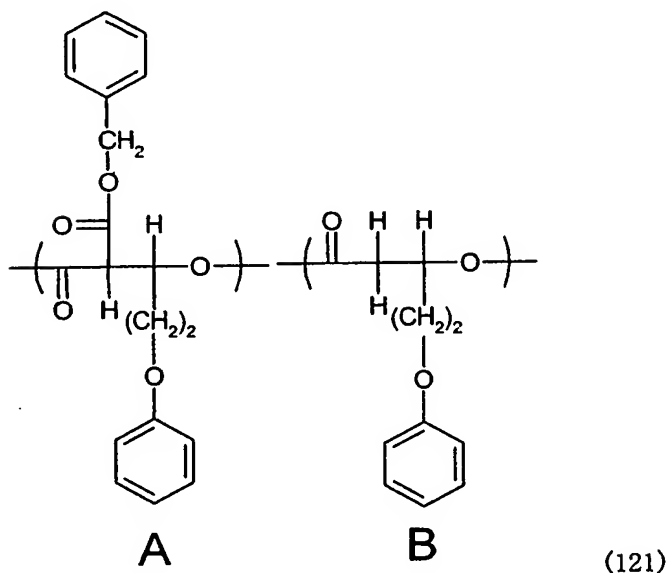


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 68,500 and a weight average molecular weight Mw of 133,600.

[Example 13]

8.29 g of a polymer was prepared in the same manner as in Example 5 except that 10.00 g of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (103) synthesized in Example 3 instead of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (101) in Example 5, 26.01 ml (52.0 mmol) of a solution of 2 M of lithium diisopropylamide in THF, and 8.88 g (104.1 mmol) of benzyl chloroformate were used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a

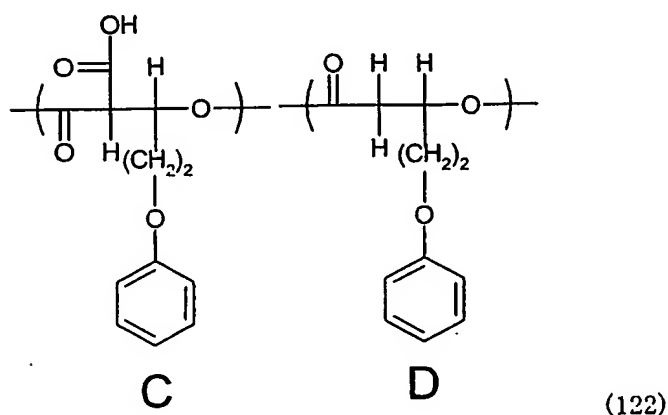
polyhydroxyalkanoate containing a unit represented by the following chemical formula (121). The analysis also confirmed that an A unit accounted for 11 mol% of the monomer unit and a B unit accounted for 89 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 131,500 and a weight average molecular weight M_w of 282,700.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.75 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis

confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (122) as a monomer unit. The analysis also confirmed that a C unit accounted for 11 mol% of the monomer unit and a D unit accounted for 89 mol% thereof.

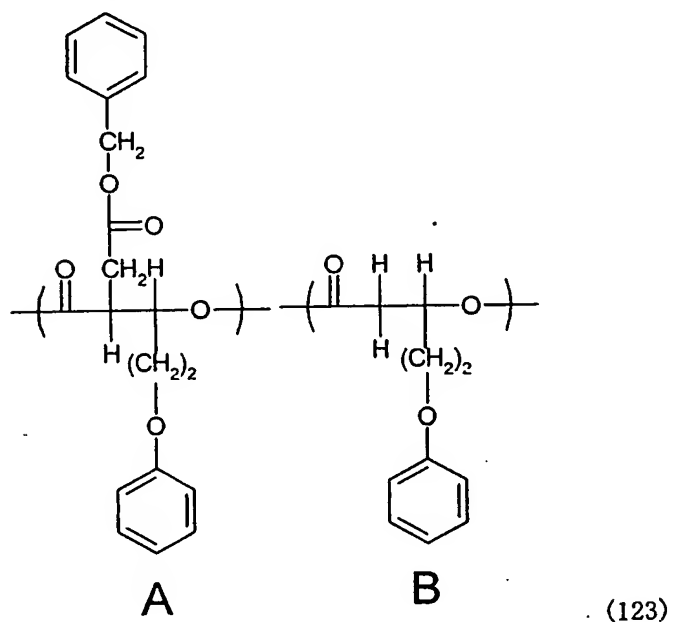


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 121,000 and a weight average molecular weight Mw of 260,200.

[Example 14]

7.70 g of a polymer was prepared in the same manner as in Example 13 except that 11.92 g (104.1 mmol) of benzyl bromoacetate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that

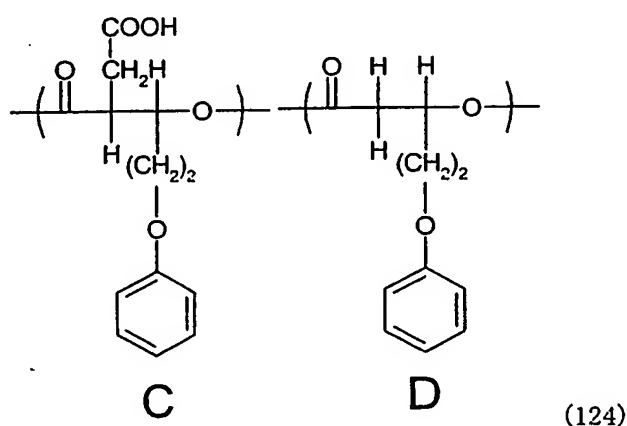
the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (123). The analysis also confirmed that an A unit accounted for 11 mol% of the monomer unit and a B unit accounted for 89 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 126,500 and a weight average molecular weight M_w of 265,700.

The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.86 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis

confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (124) as a monomer unit. The analysis also confirmed that a C unit accounted for 11 mol% of the monomer unit and a D unit accounted for 89 mol% thereof.

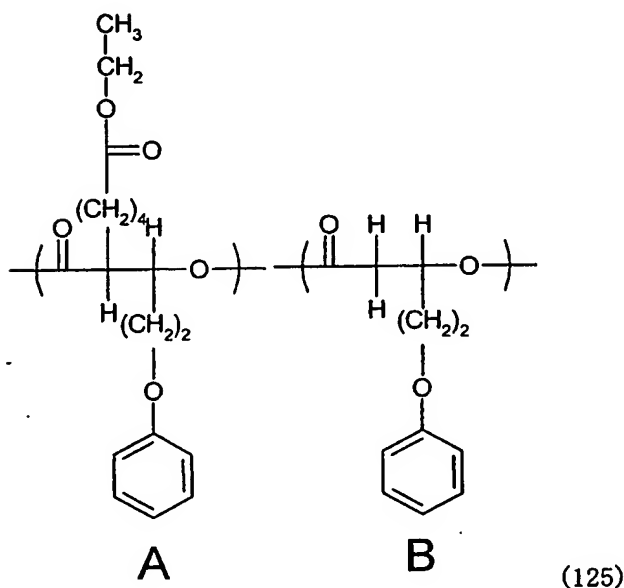


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 116,500 and a weight average molecular weight M_w of 256,300.

[Example 15]

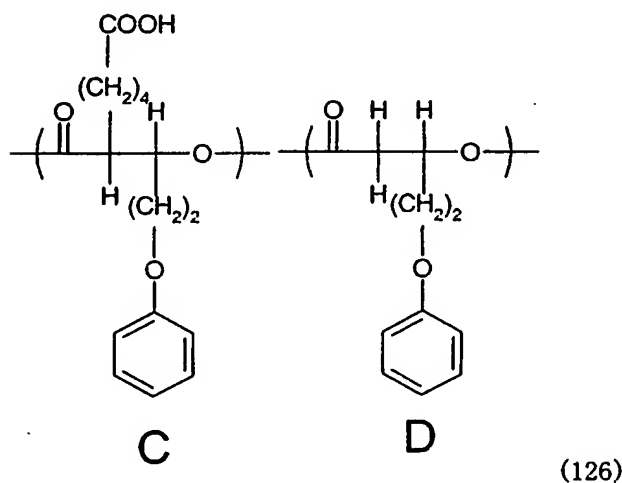
7.56 g of a polymer was prepared in the same manner as in Example 13 except that 10.88 g (104.1 mmol) of ethyl 5-bromovalerate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that

the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (125). The analysis also confirmed that an A unit accounted for 9 mol% of the monomer unit and a B unit accounted for 91 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 122,000 and a weight average molecular weight Mw of 270,800. The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.95 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer

was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (126) as a monomer unit. The analysis also confirmed that a C unit accounted for 9 mol% of the monomer unit and a D unit accounted for 91 mol% thereof.

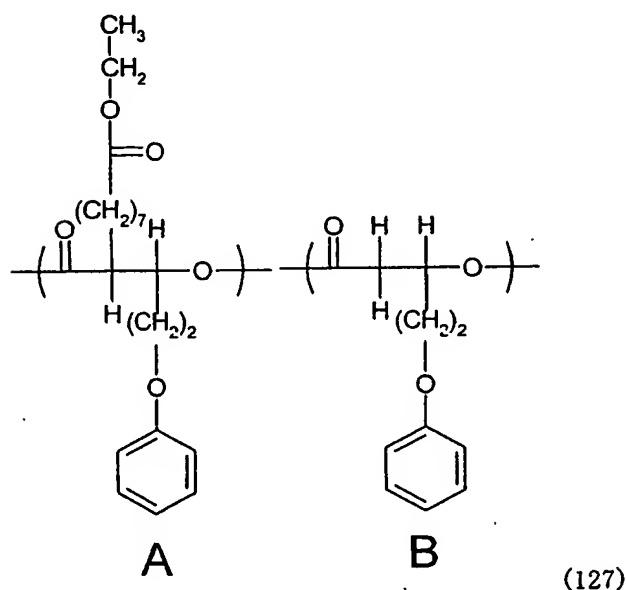


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 116,500 and a weight average molecular weight M_w of 256,300.

[Example 16]

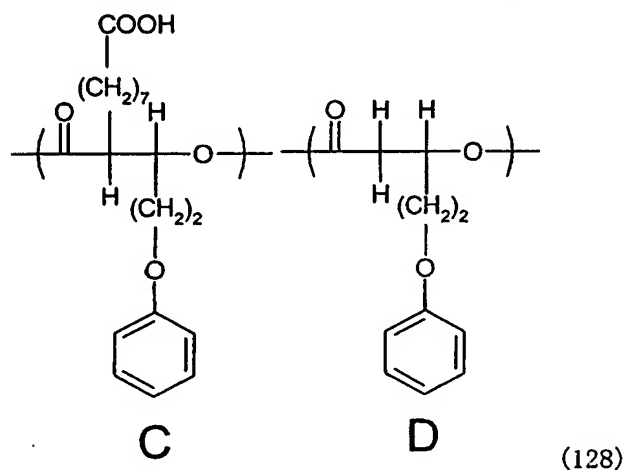
7.60 g of a polymer was prepared in the same manner as in Example 13 except that 13.07 g (104.1 mmol) of ethyl 8-bromooctanoate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that

the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (127). The analysis also confirmed that an A unit accounted for 8 mol% of the monomer unit and a B unit accounted for 92 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 134,500 and a weight average molecular weight M_w of 289,200. The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 4.01 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer

was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (128) as a monomer unit. The analysis also confirmed that a C unit accounted for 8 mol% of the monomer unit and a D unit accounted for 92 mol% thereof.

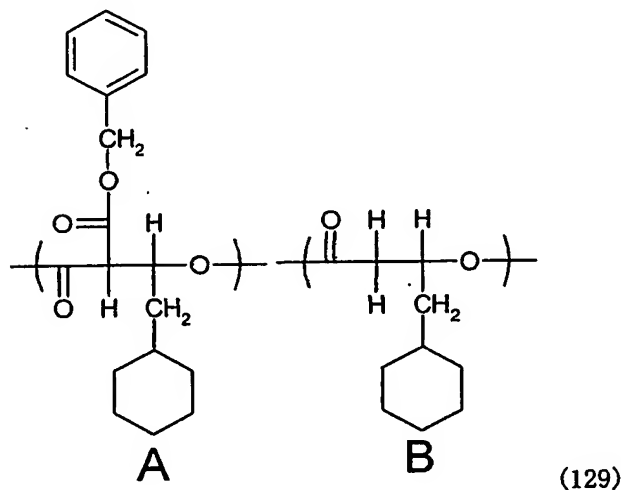


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 121,000 and a weight average molecular weight M_w of 266,200.

[Example 17]

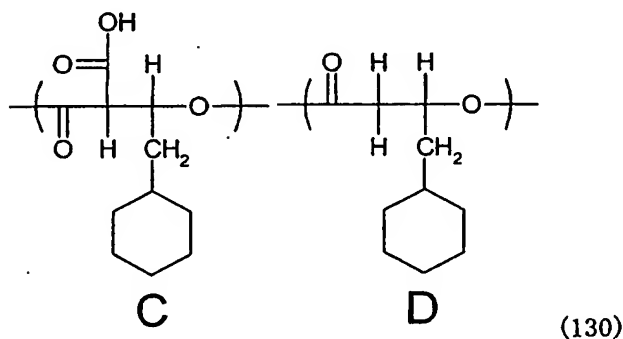
7.66 g of a polymer was prepared in the same manner as in Example 6 except that 10.00 g of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (104) synthesized in Example 4 instead of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (101) in Example 5, 29.72 ml (59.4 mmol) of a solution of 2 M

of lithium diisopropylamide in THF, and 10.14 g (118.9 mmol) of benzyl chloroformate were used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (129). The analysis also confirmed that an A unit accounted for 10 mol% of the monomer unit and a B unit accounted for 90 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 54,400 and a weight average molecular weight M_w of 11,700. The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 3.85 g of a

polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula (130) as a monomer unit. The analysis also confirmed that a C unit accounted for 10 mol% of the monomer unit and a D unit accounted for 90 mol% thereof.

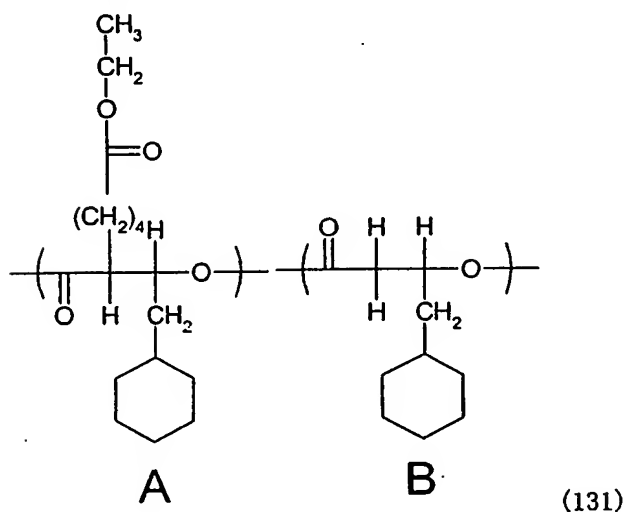


The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 47,500 and a weight average molecular weight M_w of 103,600.

[Example 18]

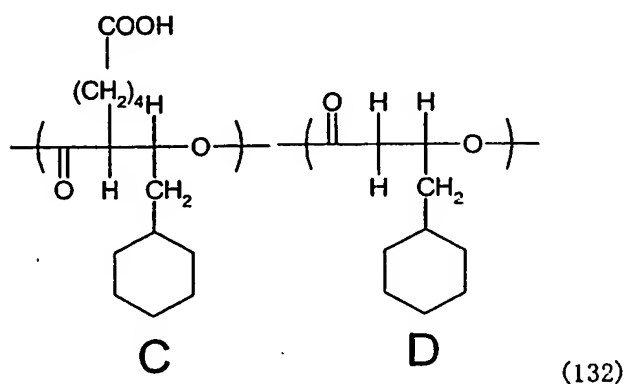
7.27 g of a polymer was prepared in the same manner as in Example 17 except that 12.43 g (118.9 mmol) of ethyl 5-bromovalerate was used instead of benzyl chloroformate. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that

the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (131). The analysis also confirmed that an A unit accounted for 9 mol% of the monomer unit and a B unit accounted for 91 mol% thereof.



The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 58,500 and a weight average molecular weight M_w of 128,700. The above polymer was subjected to hydrogenolysis in the same manner as in Example 5 to prepare 4.07 g of a polymer. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 1. The analysis confirmed that the polymer was a polyhydroxyalkanoate copolymer containing a unit represented by the following chemical formula

(132) as a monomer unit. The analysis also confirmed that a C unit accounted for 9 mol% of the monomer unit and a D unit accounted for 91 mol% thereof.



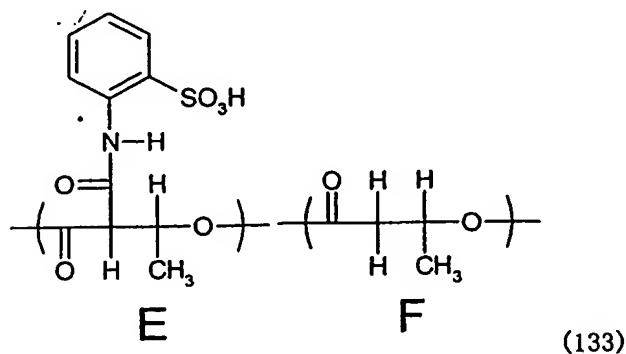
5 The average molecular weight of the resultant polyhydroxyalkanoate was measured under the same conditions as those of Example 1. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 52,100 and a weight average molecular weight M_w of 114,600.

[Example 19]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (106) synthesized in Example 5 (C: 10 mol%, D: 90 mol%) and 0.24 g (1.4 mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.71 ml (2.7 mmol) of triphenyl phosphite was added, and the whole was heated at 120°C for 6 hours. After the completion of the reaction, the

resultant was reprecipitated in 150 ml of ethanol, followed by collection. The resultant polymer was washed with 1N hydrochloric acid for 1 day, stirred in water for 1 day to wash the polymer, and dried under reduced pressure to prepare 0.35 g of a polymer. The structure of the resultant polymer was determined through analysis according to ^1H -NMR (FT-NMR: Bruker DPX 400; resonance frequency: 400 MHz; measured nuclear species: ^1H ; solvent used: DMSO- d_6 ; measurement temperature: room temperature) and Fourier transformation-infrared absorption (FT-IR) spectrum (Nicolet AVATAR 360FT-IR). As a result of IR measurement, a peak at $1,695\text{ cm}^{-1}$ derived from a carboxylic acid reduced, and a peak derived from an amide group was newly observed at $1,658\text{ cm}^{-1}$.

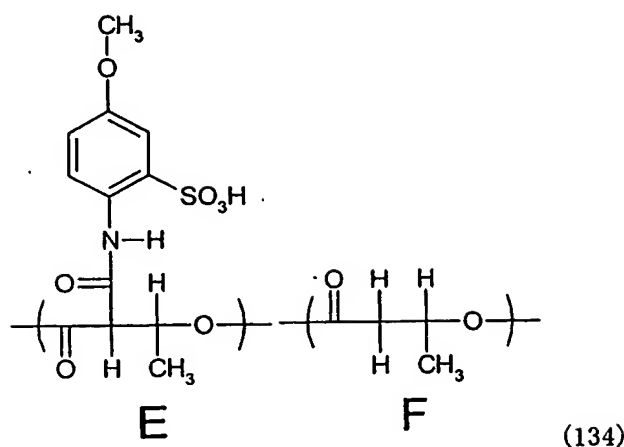
^1H -NMR confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (133) as a monomer unit because a peak derived from an aromatic ring of the 2-aminobenzenesulfonic acid structure shifted.



It was also confirmed that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 10 mol% of the unit of the polyhydroxyalkanoate represented by the chemical formula (133). The resultant polymer was evaluated for average molecular weight by means of gel permeation chromatography (GPC; Tosoh Corporation HLC-8120, column; Polymer Laboratories PLgel 5 μ MIXED-C, solvent; DMF/LiBr 0.1% (w/v), in terms of polystyrene). As a result, the resultant polymer was found to have a number average molecular weight M_n of 226,000 and a weight average molecular weight M_w of 497,200.

[Example 20]

0.33 g of a polymer was prepared in the same manner as in Example 19 except that 0.28 g (1.4 mmol) of 4-methoxyaniline-2-sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (134), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 9 mol% of the unit.

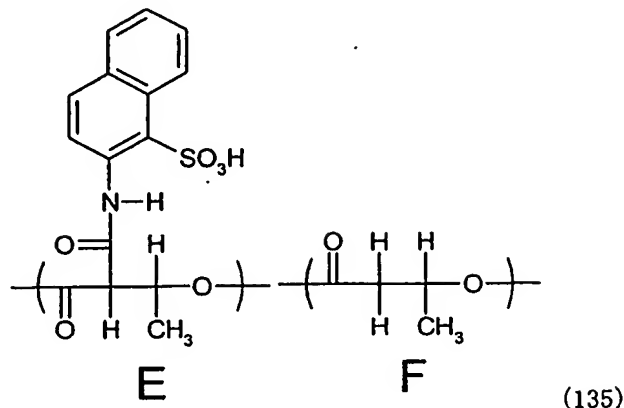


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight M_n of 218,000 and a weight average molecular weight M_w of 512,300.

[Example 21]

0.33 g of a polymer was prepared in the same manner as in Example 19 except that 0.31 g (1.4 mmol) of 2-amino-1-naphthalene sulfonic acid was used instead of 2-aminobenzenesulfonic acid. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (135), and that the polyhydroxyalkanoate was a copolymer in which an E

unit accounted for 8 mol% of the unit.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight M_n of 165,000 and a weight average molecular weight M_w of 371,300.

[Example 22]

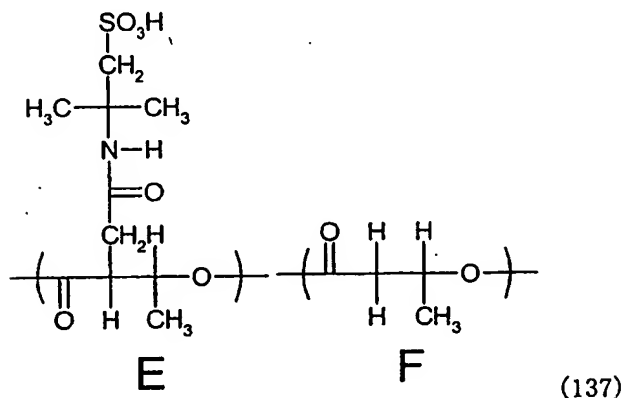
Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (108) synthesized in Example 6 (C: 11 mol%, D: 89 mol%) and 0.26 g (1.5 mmol) of 4-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.78 ml (3.0 mmol) of triphenyl phosphite was added. After that, 0.34 g of a polymer was prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and



[Example 23]

0.31 g of a polymer was prepared in the same manner as in Example 22 except that 0.23 g (1.5 mmol) of 2-amino-2-methylpropane sulfonic acid was used instead of 4-aminobenzenesulfonic acid in Example 22.

The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (137), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 9 mol% of the unit.



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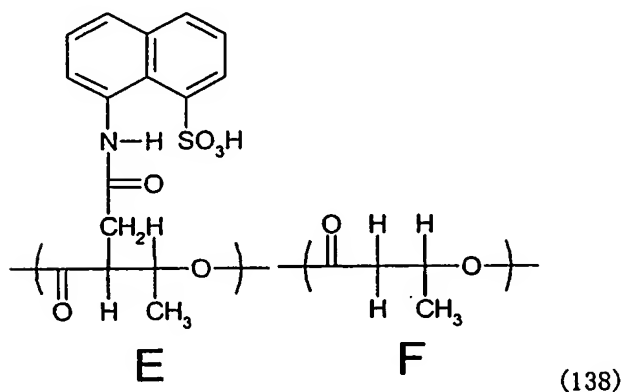
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 225,000 and a weight average molecular weight Mw of 540,000.

[Example 24]

0.35 g of a polymer was prepared in the same manner as in Example 22 except that 0.33 g (1.5 mmol) of 1-naphthylamine-8-sulfonic acid was used instead of 4-aminobenzenesulfonic acid in Example 22. The

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resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (138), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 8 mol% of the unit.



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The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight M_n of 178,000 and a weight average molecular weight M_w of 445,000.

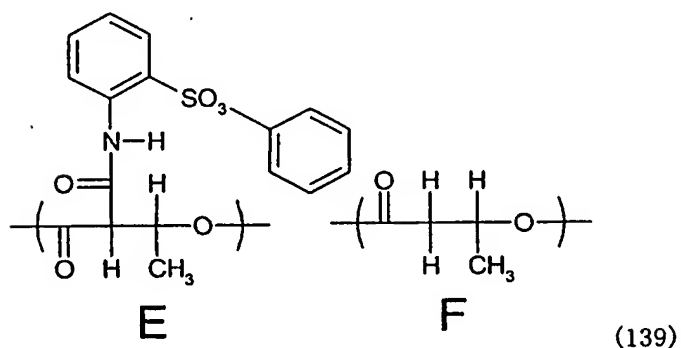
15

[Example 25]

0.37 g of a polymer was prepared in the same manner as in Example 22 except that 0.37 g (1.5 mmol) of 2-aminobenzenesulfonic acid phenyl ester was used instead of 4-aminobenzenesulfonic acid in Example 22.

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The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (139), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 9 mol% of the unit.



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The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight M_n of 210,500 and a weight average molecular weight M_w of 509,400.

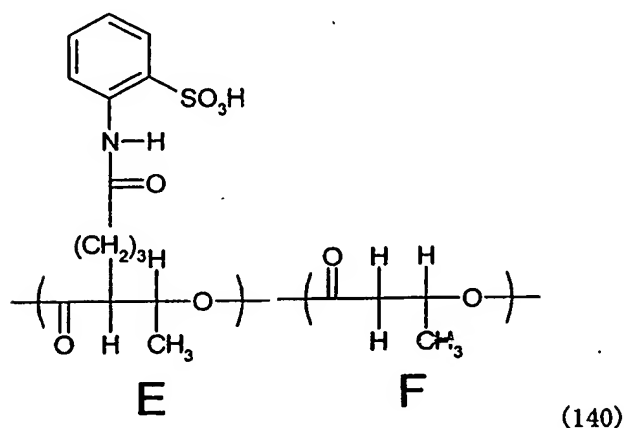
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[Example 26]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (110) synthesized in Example 7 (C: 10 mol%, D: 90 mol%) and 0.23 g (1.3

20

mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.69 ml (2.7 mmol) of triphenyl phosphite was added. After that, 0.34 g of a polymer was prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (140), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 10 mol% of the unit.

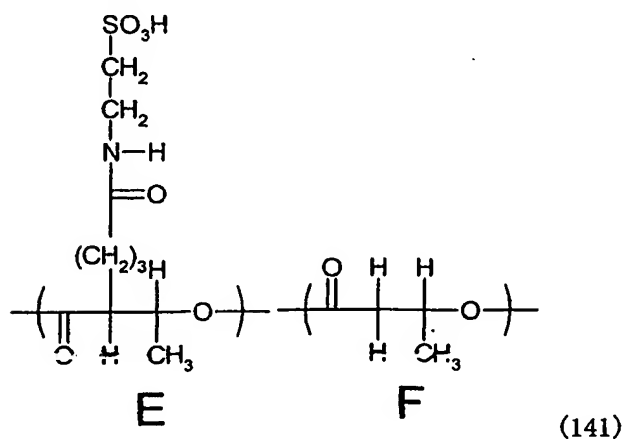


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular

weight Mn of 208,000 and a weight average molecular weight Mw of 499,200.

[Example 27]

0.29 g of a polymer was prepared in the same manner as in Example 26 except that 0.17 g (1.3 mmol) of taurine was used instead of 2-aminobenzenesulfonic acid in Example 26. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (141), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 7 mol% of the unit.

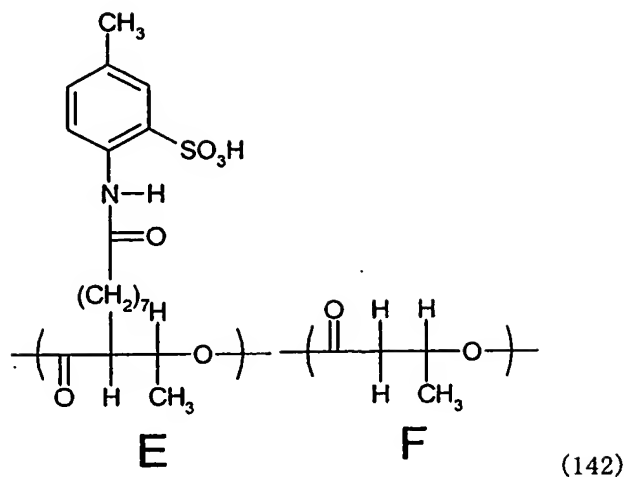


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular

weight Mn of 225,000 and a weight average molecular weight Mw of 562,500.

[Example 28]

Under a nitrogen atmosphere, 0.40 g of the
5 polyhydroxyalkanoate copolymer composed of the unit
represented by the chemical formula (112) synthesized
in Example 8 (C: 9 mol%, D: 91 mol%) and 0.22 g (1.2
mmol) of p-toluidine-2-sulfonic acid were placed in a
100-ml three-necked flask. 15.0 ml of pyridine was
10 added to the flask, and the mixture was stirred.
After that, 0.60 ml (2.3 mmol) of triphenyl phosphite
was added. After that, 0.32 g of a polymer was
prepared in the same manner as in Example 19. The
resultant polymer was subjected to NMR analysis and
15 Fourier transformation-infrared absorption spectral
analysis under the same conditions as those of
Example 19. As a result, it was confirmed that the
resultant polymer was a polyhydroxyalkanoate
containing a unit represented by the following
20 chemical formula (142), and that the
polyhydroxyalkanoate was a copolymer in which an E
unit accounted for 8 mol% of the unit.

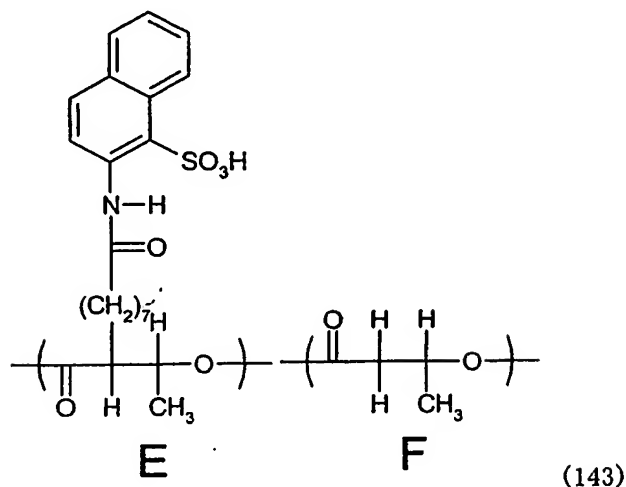


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 215,500 and a weight average molecular weight Mw of 538,800.

[Example 29]

0.34 g of a polymer was prepared in the same manner as in Example 28 except that 0.26 g (1.2 mmol) of 2-amino-1-naphthalene sulfonic acid was used instead of p-toluidine-2-sulfonic acid in Example 28. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (143), and that the

polyhydroxyalkanoate was a copolymer in which an E unit accounted for 8 mol% of the unit.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight M_n of 198,100 and a weight average molecular weight M_w of 486,300.

10 [Example 30]

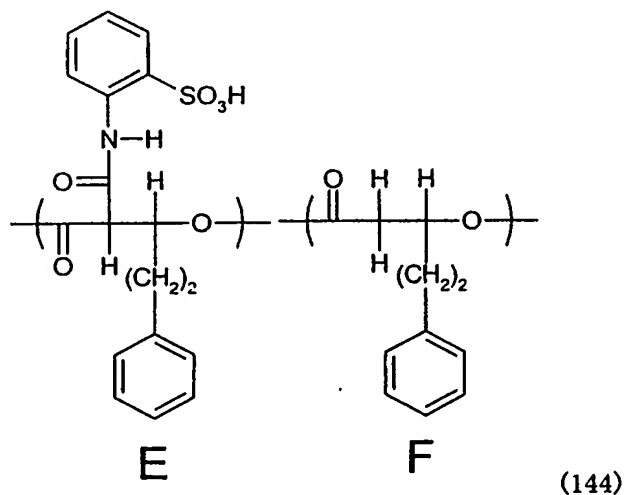
Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (114) synthesized in Example 9 (C: 12 mol%, D: 88 mol%) and 0.23 g (1.3 mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.69 ml (2.6 mmol) of triphenyl phosphite was added. After that, 0.33 g of a polymer was

prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of

5 Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (144), and that the

polyhydroxyalkanoate was a copolymer in which an E

10 unit accounted for 11 mol% of the unit.



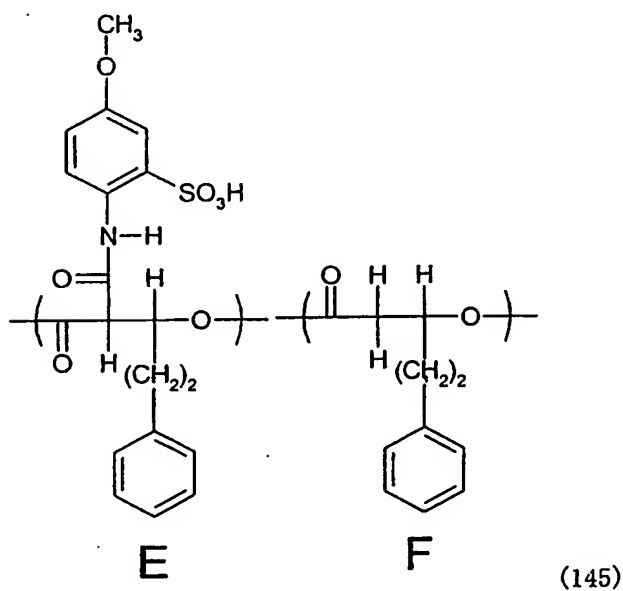
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

15 polymer was found to have a number average molecular weight M_n of 55,300 and a weight average molecular weight M_w of 113,400.

[Example 31]

0.35 g of a polymer was prepared in the same

manner as in Example 30 except that 0.27 g (1.3 mmol) of 4-methoxyaniline-2-sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 30. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (145), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 11 mol% of the unit.

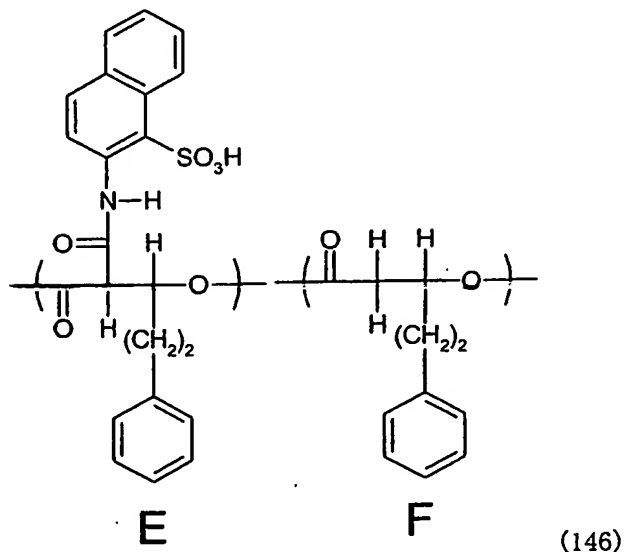


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular

weight Mn of 56,000 and a weight average molecular weight Mw of 117,600.

[Example 32]

0.31 g of a polymer was prepared in the same manner as in Example 30 except that 0.30 g (1.3 mmol) of 2-amino-1-naphthalene sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 30. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (146), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 9 mol% of the unit.

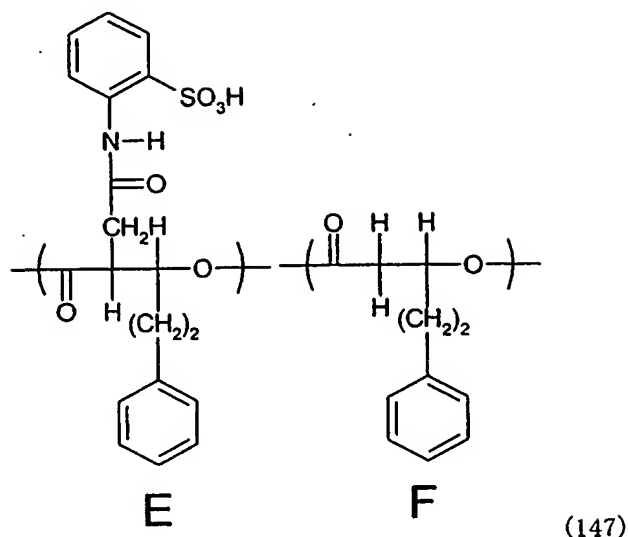


The average molecular weight of the resultant

polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 38,500 and a weight average molecular weight Mw of 82,800.

[Example 33]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (116) synthesized in Example 10 (C: 12 mol%, D: 88 mol%) and 0.19 g (1.1 mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.57 ml (2.2 mmol) of triphenyl phosphite was added. After that, 0.33 g of a polymer was prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (147), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 10 mol% of the unit.

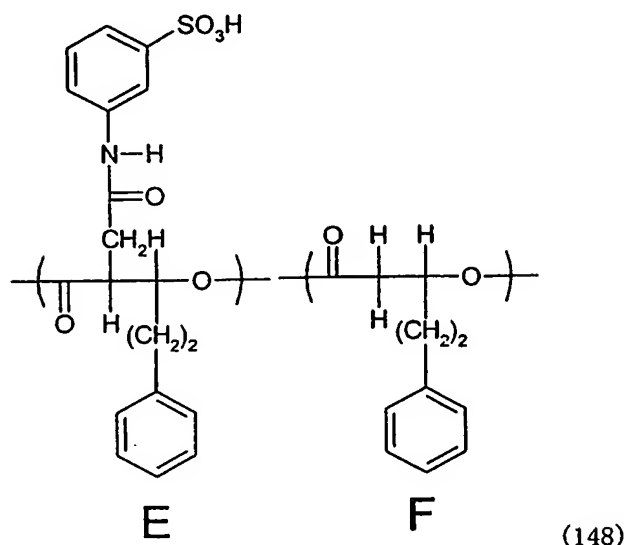


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 52,500 and a weight average molecular weight Mw of 107,600.

[Example 34]

0.33 g of a polymer was prepared in the same manner as in Example 33 except that 0.19 g (1.1 mmol) of 3-aminobenzenesulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 33. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following

chemical formula (148), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 9 mol% of the unit.



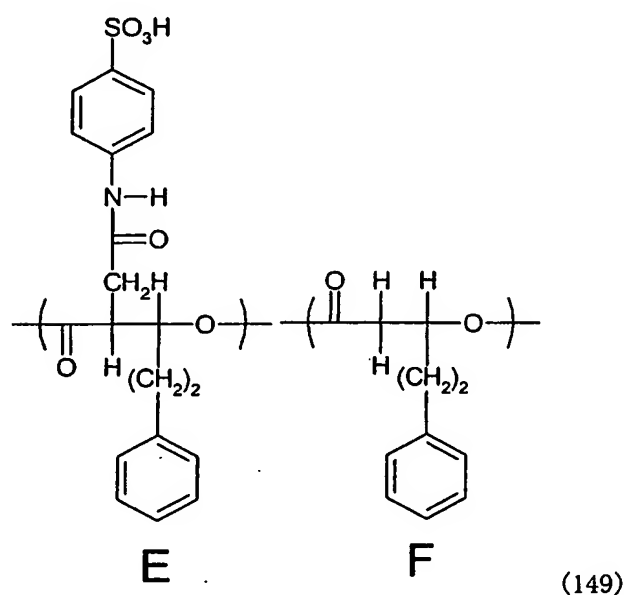
5 The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight M_n of 51,800 and a weight average molecular weight M_w of 108,800.

[Example 35]

0.35 g of a polymer was prepared in the same manner as in Example 33 except that 0.19 g (1.1 mmol) of 4-aminobenzenesulfonic acid was used instead of 15 2-aminobenzenesulfonic acid in Example 33. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of

Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (149), and that the

5 polyhydroxyalkanoate was a copolymer in which an E unit accounted for 10 mol% of the unit.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

10 polymer was found to have a number average molecular weight Mn of 51,500 and a weight average molecular weight Mw of 103,000.

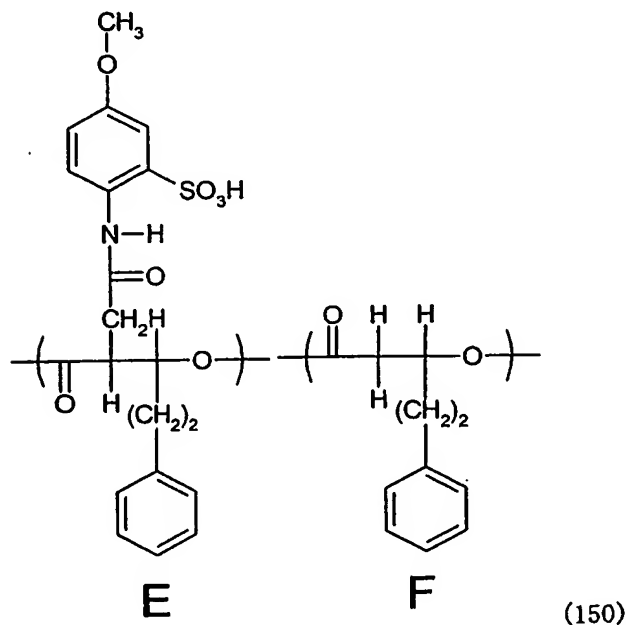
[Example 36]

15 0.37 g of a polymer was prepared in the same manner as in Example 33 except that 0.22 g (1.1 mmol) of 4-methoxyaniline-2-sulfonic acid was used instead

of 2-aminobenzenesulfonic acid in Example 33. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of

5 Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (150), and that the polyhydroxyalkanoate was a copolymer in which an E

10 unit accounted for 10 mol% of the unit.

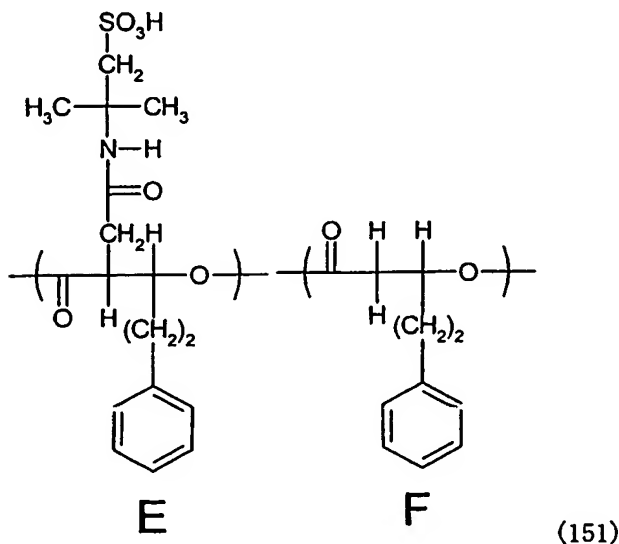


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

15 polymer was found to have a number average molecular weight M_n of 49,800 and a weight average molecular weight M_w of 102,100.

[Example 37]

0.29 g of a polymer was prepared in the same manner as in Example 33 except that 0.17 g (1.1 mmol) of 2-amino-2-methylpropane sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 33. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (151), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 8 mol% of the unit.

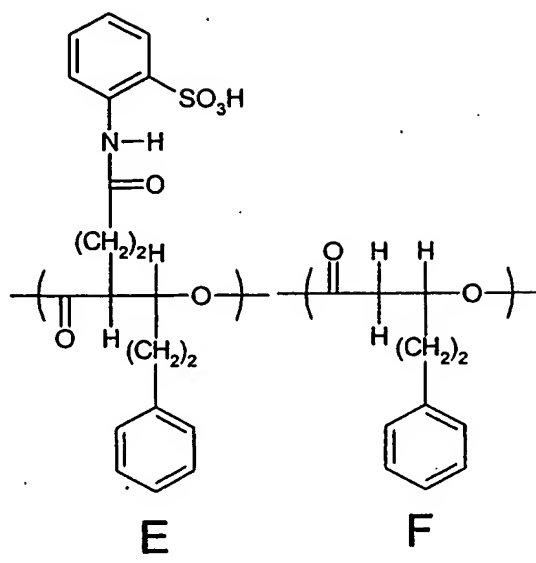


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

polymer was found to have a number average molecular weight Mn of 53,200 and a weight average molecular weight Mw of 111,700.

[Example 38]

5 Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (118) synthesized in Example 11 (C: 11 mol%, D: 89 mol%) and 0.21 g (1.2 mmol) of 2-aminobenzenesulfonic acid were placed
10 in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.62 ml (2.4 mmol) of triphenyl phosphite was added. After that, 0.33 g of a polymer was prepared in the same manner as in Example 19. The
15 resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate
20 containing a unit represented by the following chemical formula (152), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 11 mol% of the unit.

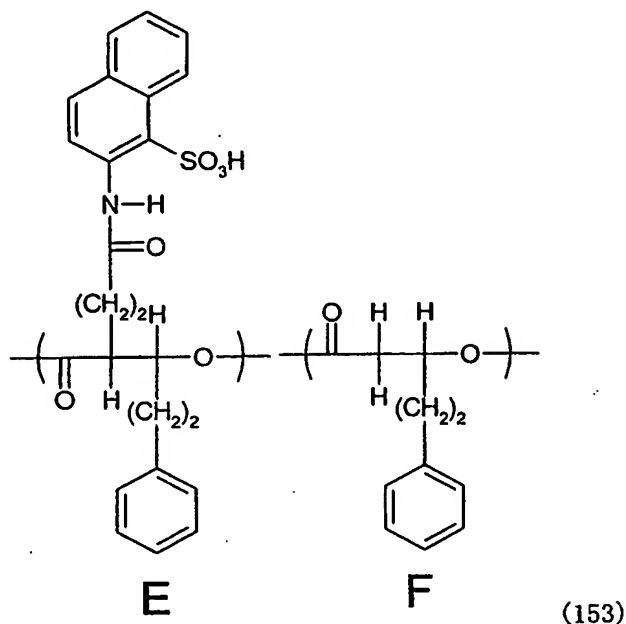


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 53,500 and a weight average molecular weight Mw of 104,300.

[Example 39]

0.33 g of a polymer was prepared in the same manner as in Example 38 except that 0.27 g (1.2 mmol) of 2-amino-1-naphthalene sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 38. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following

chemical formula (153), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 10 mol% of the unit.



5 The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 37,600 and a weight average molecular

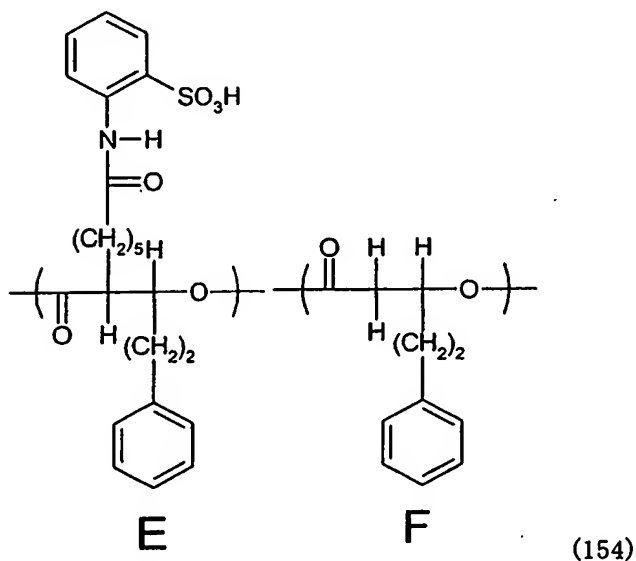
10 weight Mw of 77,100.

[Example 40]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (120) synthesized

15 in Example 12 (C: 8 mol%, D: 92 mol%) and 0.15 g (0.9 mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was

added to the flask, and the mixture was stirred.
 After that, 0.45 ml (1.7 mmol) of triphenyl phosphite
 was added. After that, 0.34 g of a polymer was
 prepared in the same manner as in Example 19. The
 5 resultant polymer was subjected to NMR analysis and
 Fourier transformation-infrared absorption spectral
 analysis under the same conditions as those of
 Example 19. As a result, it was confirmed that the
 resultant polymer was a polyhydroxyalkanoate
 10 containing a unit represented by the following
 chemical formula (154), and that the
 polyhydroxyalkanoate was a copolymer in which an E
 unit accounted for 7 mol% of the unit.

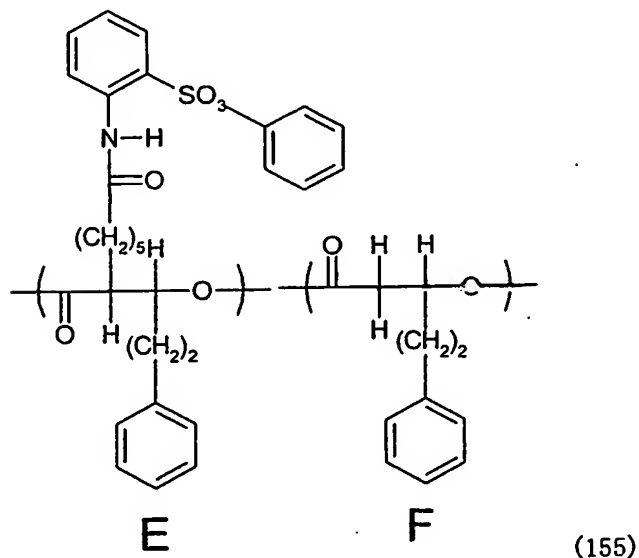


15 The average molecular weight of the resultant
 polymer was measured under the same conditions as
 those of Example 19. As a result, the resultant
 polymer was found to have a number average molecular

weight Mn of 54,200 and a weight average molecular weight Mw of 108,400.

[Example 41]

0.35 g of a polymer was prepared in the same
 5 manner as in Example 40 except that 0.22 g (0.9 mmol)
 of 2-aminobenzenesulfonic acid phenyl ester was used
 instead of 2-aminobenzenesulfonic acid in Example 40.
 The resultant polymer was subjected to NMR analysis
 and Fourier transformation-infrared absorption
 10 spectral analysis under the same conditions as those
 of Example 19. As a result, it was confirmed that
 the resultant polymer was a polyhydroxyalkanoate
 containing a unit represented by the following
 chemical formula (155), and that the
 15 polyhydroxyalkanoate was a copolymer in which an E
 unit accounted for 7 mol% of the unit.

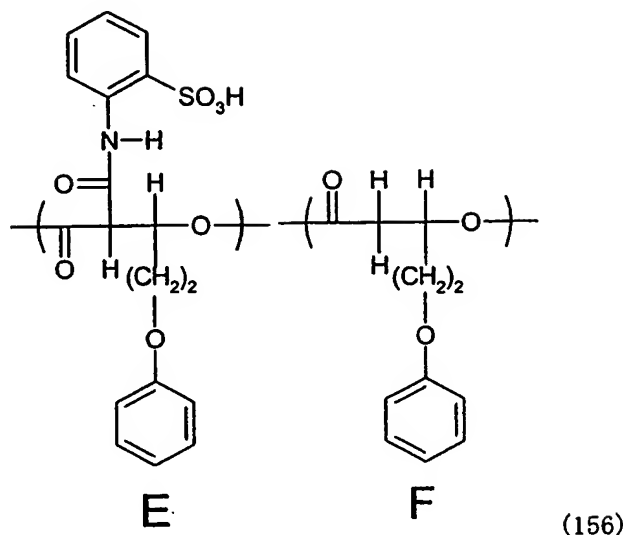


The average molecular weight of the resultant

polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 55,000 and a weight average molecular weight Mw of 104,500.

[Example 42]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (122) synthesized in Example 13 (C: 11 mol%, D: 89 mol%) and 0.19 g (1.1 mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.58 ml (2.2 mmol) of triphenyl phosphite was added. After that, 0.33 g of a polymer was prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (156), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 10 mol% of the unit.

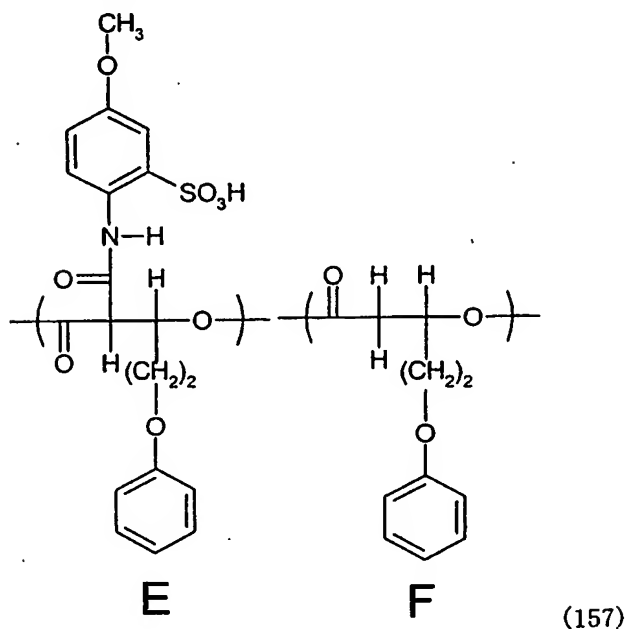


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 100,500 and a weight average molecular weight Mw of 221,100.

[Example 43]

0.35 g of a polymer was prepared in the same manner as in Example 42 except that 0.23 g (1.1 mmol) of 4-methoxyaniline-2-sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 42. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following

chemical formula (157), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 7 mol% of the unit.



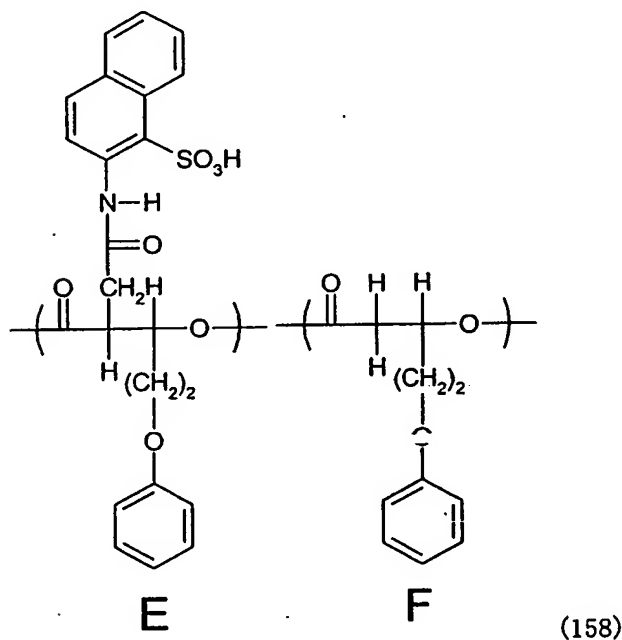
5 The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 110,200 and a weight average molecular weight Mw of 236,900.

[Example 44]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (124) synthesized in Example 14 (C: 11 mol%, D: 89 mol%) and 0.25 g (1.1 mmol) of 2-amino-1-naphthalene sulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of

pyridine was added to the flask, and the mixture was stirred. After that, 0.58 ml (2.2 mmol) of triphenyl phosphite was added. After that, 0.34 g of a polymer was prepared in the same manner as in Example 19.

- 5 The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate
10 containing a unit represented by the following chemical formula (158), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 11 mol% of the unit.



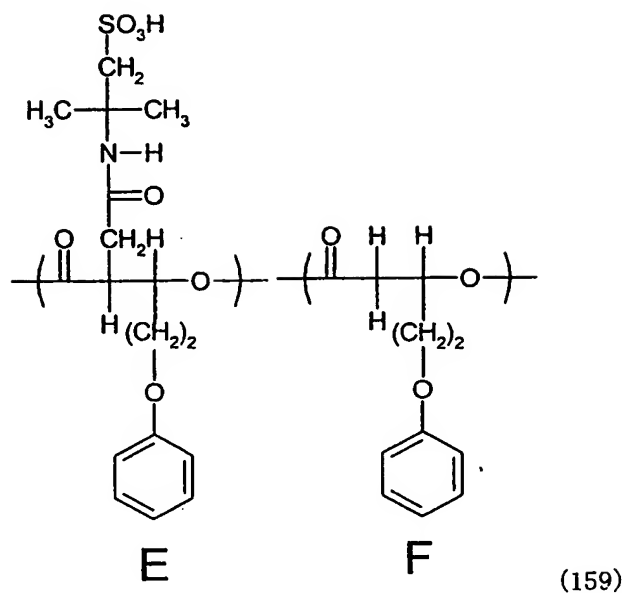
- 15 The average molecular weight of the resultant polymer was measured under the same conditions as

those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 87,500 and a weight average molecular weight Mw of 192,500.

5 [Example 45]

0.33 g of a polymer was prepared in the same manner as in Example 44 except that 0.17 g (1.1 mmol) of 2-amino-2-methylpropane sulfonic acid was used instead of 2-aminobenzenesulfonic acid in Example 44.

- 10 The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate
- 15 containing a unit represented by the following chemical formula (159), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 7 mol% of the unit.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 99,800 and a weight average molecular weight Mw of 214,600.

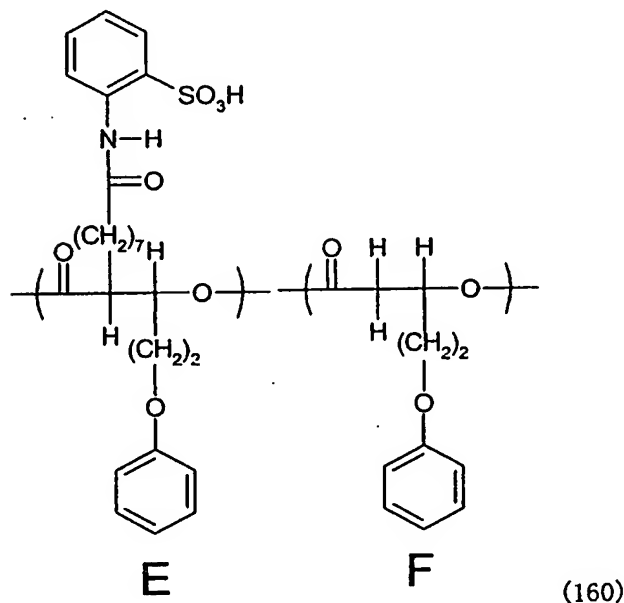
[Example 46]

Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (128) synthesized in Example 16 (C: 8 mol%, D: 92 mol%) and 0.15 g (0.9 mmol) of 2-aminobenzenesulfonic acid were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.46 ml (1.8 mmol) of triphenyl phosphite was added. After that, 0.33 g of a polymer was

prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of

5 Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (160), and that the

10 polyhydroxyalkanoate was a copolymer in which an E unit accounted for 8 mol% of the unit.

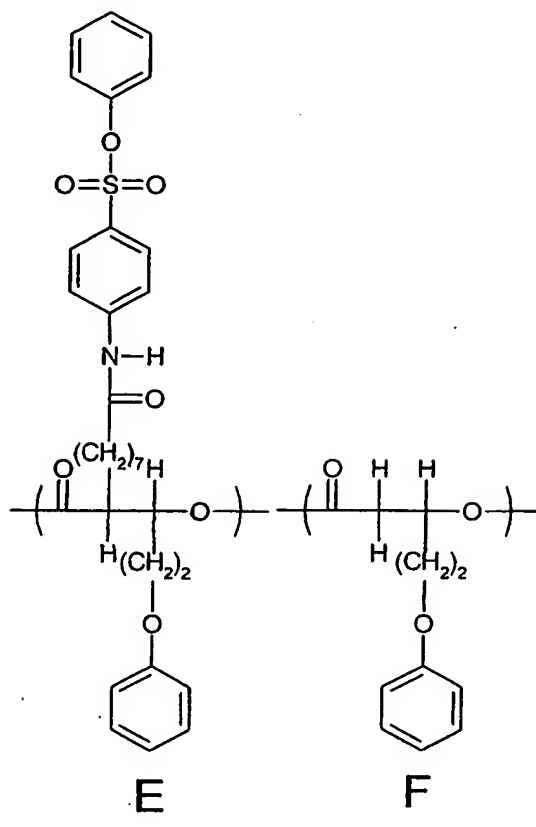


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

15 polymer was found to have a number average molecular weight M_n of 100,100 and a weight average molecular weight M_w of 225,200.

[Example 47]

0.33 g of a polymer was prepared in the same manner as in Example 46 except that 0.22 g (0.9 mmol) of 4-aminobenzenesulfonic acid phenyl ester was used instead of 2-aminobenzenesulfonic acid in Example 46. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (161), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 7 mol% of the unit.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

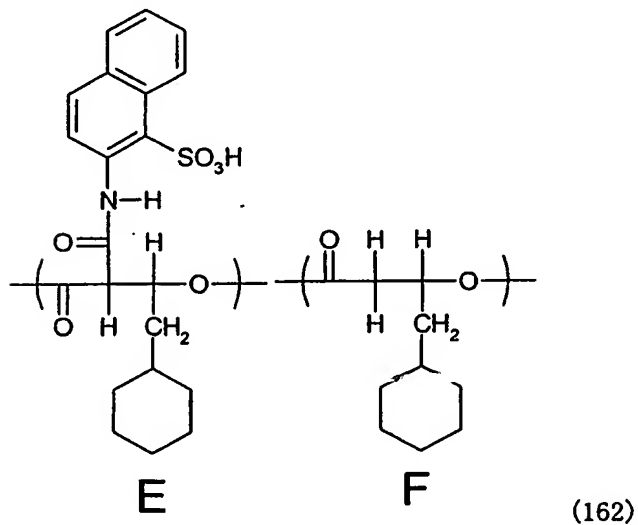
5 polymer was found to have a number average molecular weight Mn of 110,500 and a weight average molecular weight Mw of 237,600.

[Example 48]

Under a nitrogen atmosphere, 0.40 g of the

10 polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (130) synthesized in Example 17 (C: 10 mol%, D: 90 mol%) and 0.26 g (1.2 mmol) of 2-amino-1-naphthalene sulfonic acid

were placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.60 ml (2.3 mmol) of triphenyl phosphite was added. After that, 0.36 g of a polymer was prepared in the same manner as in Example 19. The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (162), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 9 mol% of the unit.

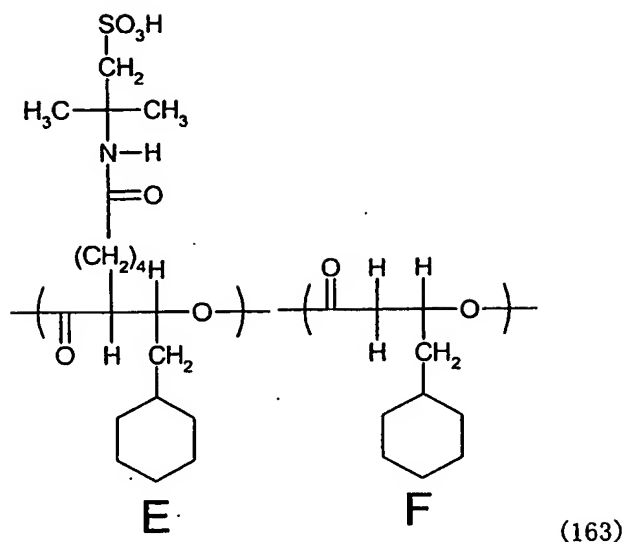


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant

polymer was found to have a number average molecular weight Mn of 30,500 and a weight average molecular weight Mw of 65,600.

[Example 49]

- 5 Under a nitrogen atmosphere, 0.40 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (132) synthesized in Example 18 (C: 9 mol%, D: 91 mol%) and 0.16 g (1.0 mmol) of 2-amino-2-methylpropane sulfonic acid were
10 placed in a 100-ml three-necked flask. 15.0 ml of pyridine was added to the flask, and the mixture was stirred. After that, 0.52 ml (2.0 mmol) of triphenyl phosphite was added. After that, 0.31 g of a polymer was prepared in the same manner as in Example 19.
- 15 The resultant polymer was subjected to NMR analysis and Fourier transformation-infrared absorption spectral analysis under the same conditions as those of Example 19. As a result, it was confirmed that the resultant polymer was a polyhydroxyalkanoate
20 containing a unit represented by the following chemical formula (163), and that the polyhydroxyalkanoate was a copolymer in which an E unit accounted for 8 mol% of the unit.

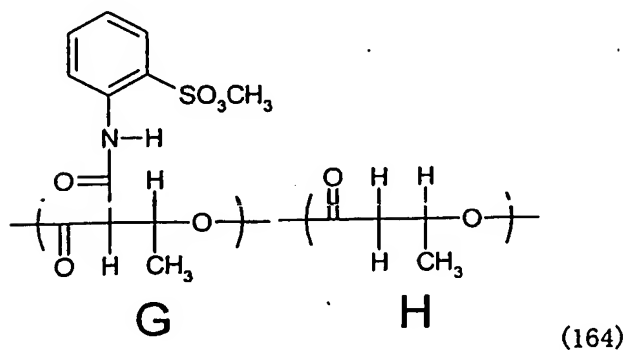


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 19. As a result, the resultant polymer was found to have a number average molecular weight Mn of 32,500 and a weight average molecular weight Mw of 71,500.

[Example 50]

0.30 g of the polyhydroxyalkanoate copolymer composed of the unit represented by the chemical formula (133) synthesized in Example 19 was added to a round-bottomed flask. Then, 21.0 ml of chloroform and 7.0 ml of methanol were added to dissolve the polymer, and the solution was cooled to 0°C. 0.93 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was added to the solution, and the whole was stirred for 4 hours. After the completion of the reaction, the solvent was

distilled off by using an evaporator, and then the polymer was collected. Furthermore, 21.0 ml of chloroform and 7.0 ml of methanol were added to dissolve the polymer again. Then, the solvent was distilled off by using an evaporator. This operation was repeated 3 times. The collected polymer was dried under reduced pressure to prepare 0.30 g of a polymer. The structure of the resultant polymer was determined through analysis according to ^1H -NMR (FT-NMR: Bruker DPX 400; resonance frequency: 400 MHz; measured nuclear species: ^1H ; solvent used: DMSO- d_6 ; measurement temperature: room temperature). ^1H -NMR confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (164) as a monomer unit because a peak derived from methyl sulfonate was observed at 3 to 4 ppm.



It was also confirmed that a G unit accounted for 10 mol% of the unit of the polyhydroxyalkanoate represented by the chemical formula (164). In

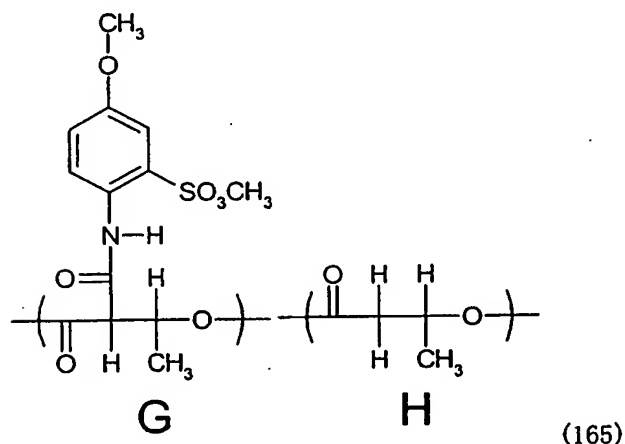
addition, there was no peak observed resulted from sulfonic acid in acid value titration using Potentiometric Titrator AT510 (product of Kyoto Electronics Manufacturing Co., Ltd.) and it was also
5 made evident from this that sulfonic acid was converted to methyl sulfonate. The resultant polymer was evaluated for average molecular weight by means of gel permeation chromatography (GPC; Tosoh Corporation HLC-8120, column; Polymer Laboratories
10 PLgel 5 μ MIXED-C, solvent; DMF/LiBr 0.1% (w/v), in terms of polystyrene). As a result, the resultant polymer was found to have a number average molecular weight Mn of 228,000 and a weight average molecular weight Mw of 513,000.

15 [Example 51]

0.29 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (134) synthesized in Example 20 was used
20 instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.83 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis
25 under the same conditions as those of Example 50. The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented

by the following chemical formula (165), and that the polyhydroxyalkanoate was a copolymer in which a G unit accounted for 9 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.



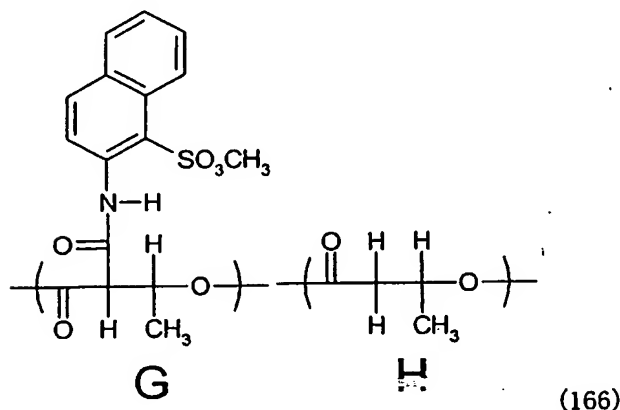
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight M_n of 209,000 and a weight average molecular weight M_w of 480,700.

[Example 52]

0.30 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (135) synthesized in Example 21 was used instead of the polyhydroxyalkanoate represented by

the chemical formula (133) synthesized in Example 50, and 0.71 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis
 5 under the same conditions as those of Example 50. The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (166), and that the polyhydroxyalkanoate was a copolymer in which a G
 10 unit accounted for 8 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.



15

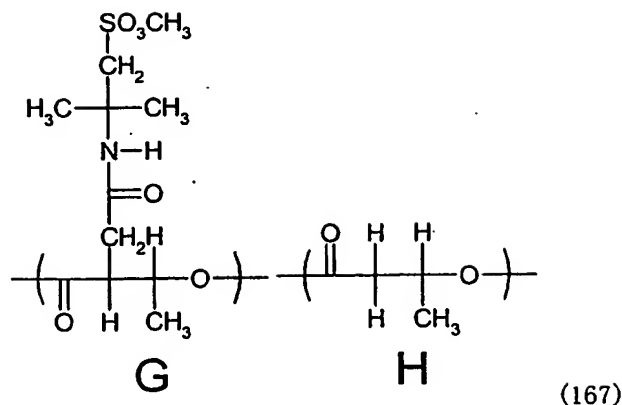
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular
 20 weight M_n of 162,500 and a weight average molecular

weight Mw of 373,800.

[Example 53]

0.29 g of a polymer was prepared in the same manner as in Example 50 except that the
5 polyhydroxyalkanoate represented by the chemical formula (137) synthesized in Example 23 was used instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.83 ml of a 2-mol/L trimethylsilyldiazomethane-
10 hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 50. The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented
15 by the following chemical formula (167), and that the polyhydroxyalkanoate was a copolymer in which a G unit accounted for 9 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic
20 acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.



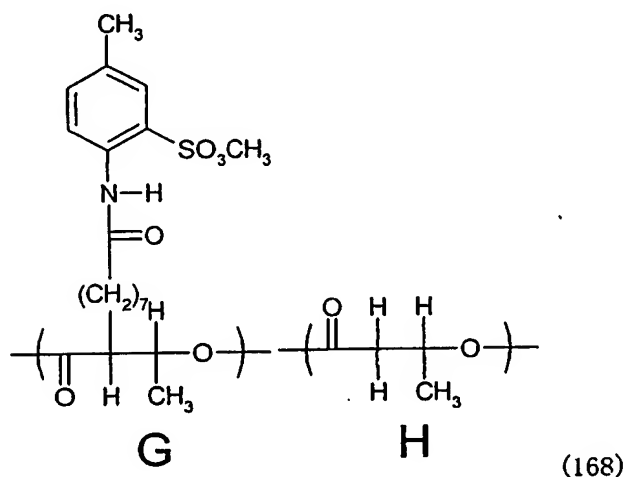
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight Mn of 228,500 and a weight average molecular weight Mw of 548,400.

[Example 54]

0.30 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (142) synthesized in Example 28 was used instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.71 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 50. The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (168), and that the

polyhydroxyalkanoate was a copolymer in which a G unit accounted for 8 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no
5 acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.

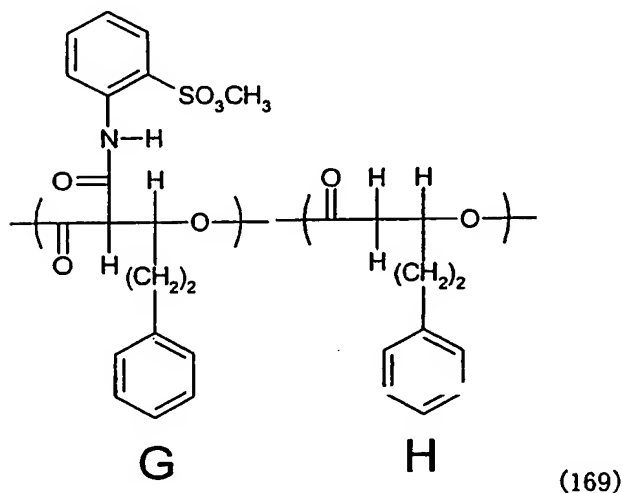


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant
10 polymer was found to have a number average molecular weight Mn of 218,000 and a weight average molecular weight Mw of 555,900.

[Example 55]

0.29 g of a polymer was prepared in the same
15 manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (144) synthesized in Example 30 was used instead of the polyhydroxyalkanoate represented by

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.



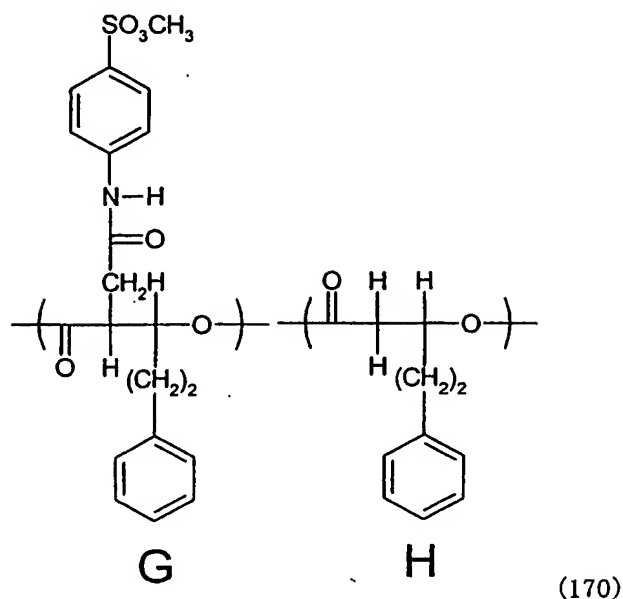
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular

weight Mn of 54,500 and a weight average molecular weight Mw of 114,500.

[Example 56]

0.29 g of a polymer was prepared in the same
5 manner as in Example 50 except that the
polyhydroxyalkanoate represented by the chemical
formula (149) synthesized in Example 35 was used
instead of the polyhydroxyalkanoate represented by
the chemical formula (133) synthesized in Example 50,
10 and 0.76 ml of a 2-mol/L trimethylsilyldiazomethane-
hexane solution (manufactured by Aldrich) was used.
The resultant polymer was subjected to NMR analysis
under the same conditions as those of Example 50.
The analysis confirmed that the resultant polymer was
15 a polyhydroxyalkanoate containing a unit represented
by the following chemical formula (170), and that the
polyhydroxyalkanoate was a copolymer in which a G
unit accounted for 10 mol% of the unit.

In addition, acid value titration in the same
20 manner as in Example 50 revealed that the sulfonic
acid was transformed into methyl sulfonate because no
peak derived from the sulfonic acid was observed.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight Mn of 51,000 and a weight average molecular weight Mw of 104,600.

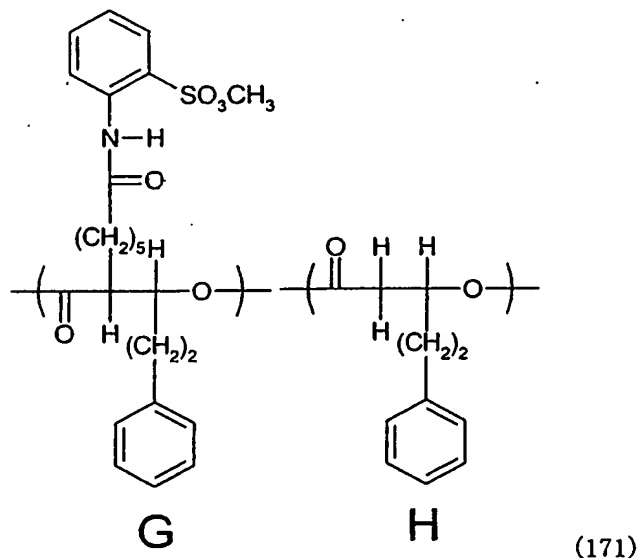
[Example 57]

0.30 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (154) synthesized in Example 40 was used instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.54 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis

under the same conditions as those of Example 50.

The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (171), and that the polyhydroxyalkanoate was a copolymer in which a G unit accounted for 7 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.

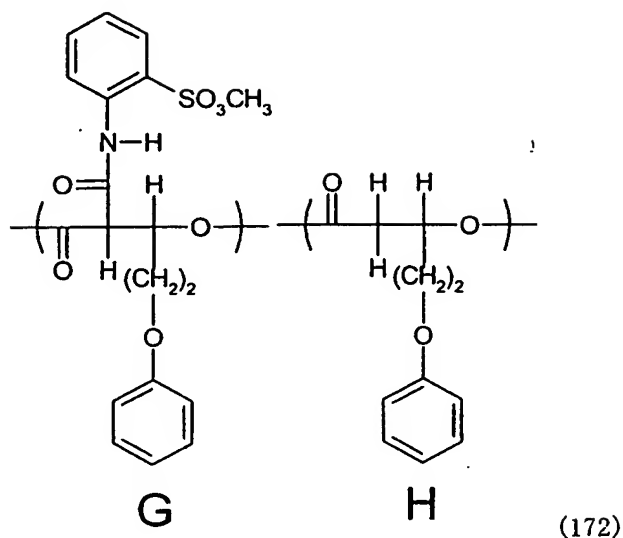


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight M_n of 52,500 and a weight average molecular weight M_w of 110,300.

[Example 58]

0.30 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (156) synthesized in Example 42 was used instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.71 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 50. The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (172), and that the polyhydroxyalkanoate was a copolymer in which a G unit accounted for 10 mol% of the unit.

In addition, oxidation titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.



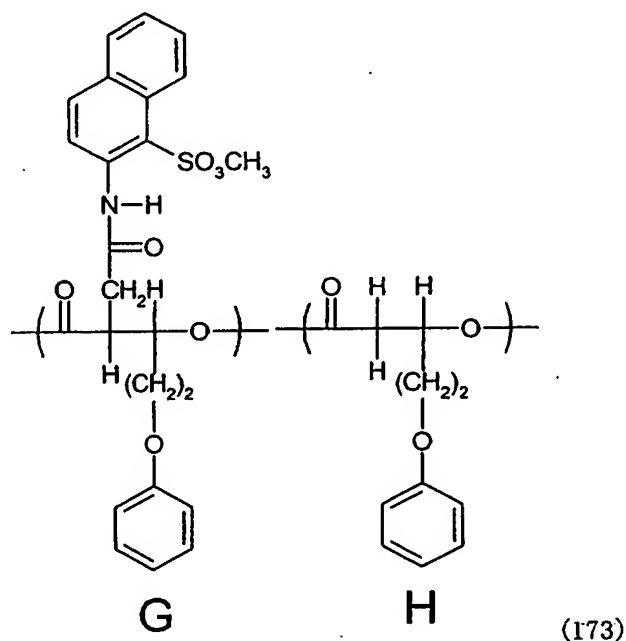
The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight Mn of 101,000 and a weight average molecular weight Mw of 227,300.

[Example 59]

0.29 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (156) synthesized in Example 44 was used instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.75 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used. The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 50.

The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (173), and that the polyhydroxyalkanoate was a copolymer in which a G unit accounted for 11 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.



10

The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight M_n of 86,500 and a weight average molecular weight M_w of 186,000.

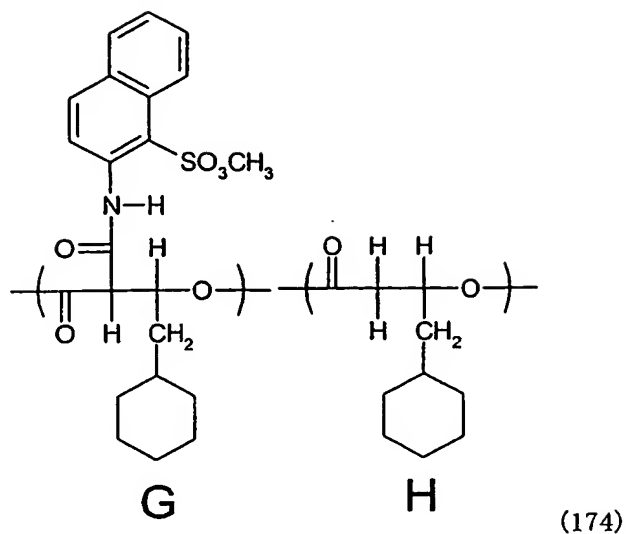
15

[Example 60]

0.28 g of a polymer was prepared in the same manner as in Example 50 except that the polyhydroxyalkanoate represented by the chemical formula (162) synthesized in Example 48 was used instead of the polyhydroxyalkanoate represented by the chemical formula (133) synthesized in Example 50, and 0.71 ml of a 2-mol/L trimethylsilyldiazomethane-hexane solution (manufactured by Aldrich) was used.

The resultant polymer was subjected to NMR analysis under the same conditions as those of Example 50. The analysis confirmed that the resultant polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (174), and that the polyhydroxyalkanoate was a copolymer in which a G unit accounted for 9 mol% of the unit.

In addition, acid value titration in the same manner as in Example 50 revealed that the sulfonic acid was transformed into methyl sulfonate because no peak derived from the sulfonic acid was observed.

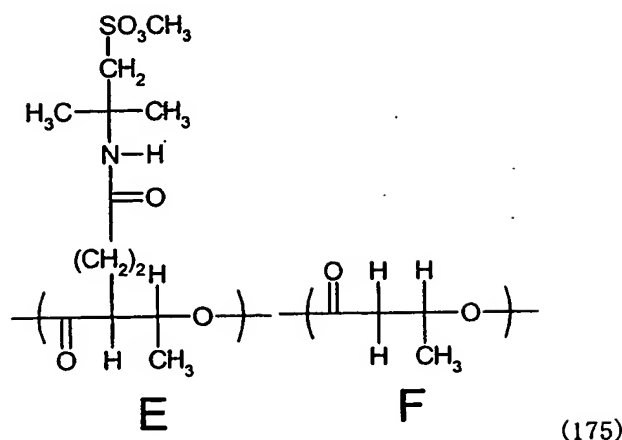


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polymer was found to have a number average molecular weight Mn of 31,000 and a weight average molecular weight Mw of 68,200.

[Example 61]

2.00 g of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (101) synthesized in Example 1 was placed in a round-bottomed flask, and 100 ml of THF was added to dissolve this. The flask was placed under a nitrogen atmosphere, and the solution was stirred at -78°C . Next, 11.62 ml of a solution of 2 M of lithium diisopropylamide in THF was gradually added to the flask, and the whole was stirred at -78°C for 30 minutes. Next, 10.19 g of 2-acrylamide-2-

methylpropanesulfonic acid methyl ester were added to the flask, and the whole was stirred at room temperature for 30 minutes. After the completion of the reaction, the reaction solution was poured into
5 400 ml of an aqueous solution of ammonium chloride, and 200 ml of dichloromethane were added to extract the organic layer. The extracted organic layer was washed with 100 ml of water 3 times. After the organic layer had been collected, the solvent was
10 distilled off to collect a crude polymer. Next, the polymer was dissolved into 12 ml of THF, then dissolved into THF, and reprecipitated in methanol in an amount 50 times that of THF necessary for the dissolution. The precipitate was collected and dried
15 under reduced pressure to prepare 1.63 g of a polymer. The structure of the resultant polymer was determined through analysis according to ^1H -NMR (FT-NMR: Bruker DPX 400; resonance frequency: 400 MHz; measured nuclear species: ^1H ; solvent used: DMSO- d_6 ;
20 measurement temperature: room temperature). The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (175) as a monomer unit. The analysis also confirmed that an E unit
25 accounted for 9 mol% of the monomer unit and an F unit accounted for 91 mol% thereof.

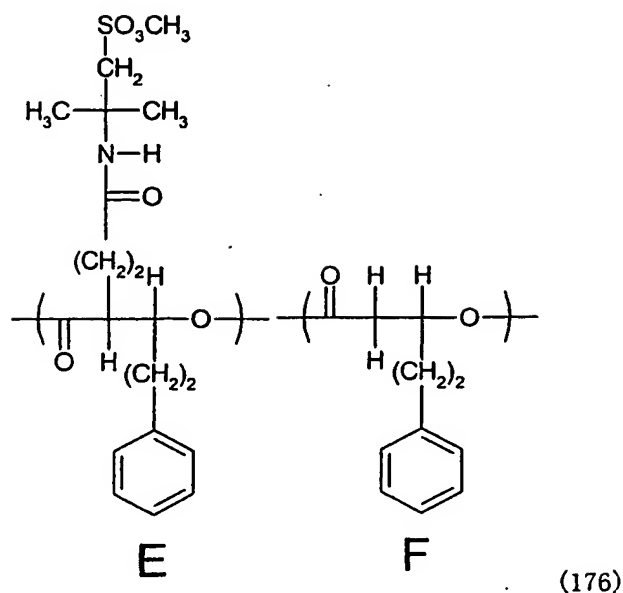


The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight Mn of 286,500 and a weight average molecular weight Mw of 572,500.

[Example 62]

2.00 g of the polyhydroxyalkanoate composed of the unit represented by the chemical formula (102) synthesized in Example 2 was placed in a round-bottomed flask, and 100 ml of THF was added to dissolve this. The flask was placed under a nitrogen atmosphere, and the solution was stirred at -78°C . Next, 5.68 ml of a solution of 2 M of lithium diisopropylamide in THF was gradually added to the flask, and the whole was stirred at -78°C for 30 minutes. Next, 4.98 g of 2-acrylamide-2-methylpropanesulfonic acid methyl ester was added to the flask, and the whole was stirred at room

temperature for 30 minutes. After the completion of the reaction, the reaction solution was poured into 400 ml of an aqueous solution of ammonium chloride, and 200 ml of dichloromethane was added to extract the organic layer. The extracted organic layer was washed with 100 ml of water 3 times. After the organic layer had been collected, the solvent was distilled off to collect a crude polymer. Next, the polymer was dissolved into 12 ml of THF, then dissolved into THF, and reprecipitated in methanol in an amount 50 times that of THF necessary for the dissolution. The precipitate was collected and dried under reduced pressure to prepare 1.22 g of a polymer. The structure of the resultant polymer was determined through analysis according to ^1H -NMR (FT-NMR: Bruker DPX 400; resonance frequency: 400 MHz; measured nuclear species: ^1H ; solvent used: DMSO- d_6 ; measurement temperature: room temperature). The analysis confirmed that the polymer was a polyhydroxyalkanoate containing a unit represented by the following chemical formula (176) as a monomer unit. The analysis also confirmed that an E unit accounted for 8 mol% of the monomer unit and an F unit accounted for 92 mol% thereof.



The average molecular weight of the resultant polymer was measured under the same conditions as those of Example 50. As a result, the resultant polyhydroxyalkanoate was found to have a number average molecular weight M_n of 56,500 and a weight average molecular weight M_w of 112,300.

INDUSTRIAL APPLICABILITY

According to the present invention, there is provided: a novel polyhydroxyalkanoate containing, in a molecule, a carboxyl group as a reaction active group at a side-chain thereof; a novel polyhydroxyalkanoate containing, in a molecule, a unit having an amide group and a sulfonic group; and a method of producing such a polyhydroxyalkanoate. A novel polyhydroxyalkanoate having a carboxyl group

can find applications in functional materials because it can introduce a functional group which provides functionalities by using its reaction active group. Furthermore, a polyhydroxyalkanoate containing, in a molecule, a unit having a carboxyl group, an amide group, or a sulfonic group is expected to find use in applications including medical soft members because it is excellent in melt processability, and is excellent in biocompatibility by virtue of its hydrophilicity.

This application claims priority from Japanese Patent Application Nos. 2004-174783 filed June 11, 2004 and 2005-168916 filed June 8, 2005, which are hereby incorporated by reference herein.